THE UNIVERSITY OF TEXAS BULLETIN
No. 3619: May 15, 1936

THE JACKSON GROUP AND THE CATAHOULA AND OAKVILLE FORMATIONS IN A PART OF THE TEXAS GULF COASTAL PLAIN

By

B. COLEMAN RENICK

Bureau of Economic Geology
E. H. Sellards, Director

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PUBLISHED BY THE UNIVERSITY FOUR TIMES A MONTH AND ENTERED AS SECOND-CLASS MATTER AT THE POSTOFFICE AT AUSTIN, TEXAS, UNDER THE ACT OF AUGUST 24, 1912

The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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THE JACKSON GROUP AND THE CATAHOULA AND OAKVILLE FORMATIONS IN A PART OF THE TEXAS GULF COASTAL PLAIN[1]

B. COLEMAN RENICK[2]

INTRODUCTION

The field work on which this paper is based was carried on at intervals between 1928 and 1933, but all the data have been rechecked in the field between 1932 and 1934. The upper Yegua formation, the Jackson group, the Catahoula formation, and the lower part of the Oakville formation have been mapped between western Walker County and Guadalupe River in Gonzales County.

While this paper was being prepared, several contributions appeared which describe at least part of the same section of rocks, namely, those of Bowling and Wendler[3] and Ellisor.[4] Plummer[5] has also recently made a very valuable contribution to the Tertiary geology of Texas. His book with the accompanying complete bibliography has been of considerable service in connection with the examination of the literature, which is so scattered and voluminous.

This paper, therefore, contains some information which has previously been published. However, in view of the fact that it is based on nearly complete mapping of the formations described across a considerable area in the Gulf Coastal Plain and contains additional data, which have not hitherto been published, it was considered desirable to complete it for publication. The stratigraphy is the main topic of this paper but the principal structural features are also discussed.

The geological sections described below are based entirely upon surface examination of the rocks and do not consider the relationships of the formations as found downdip to the southeast where

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[1]Presented in brief at the annual meeting of the San Antonio Geological Society at Corpus Christi, Texas, October 28, 1933, under title of "Surface Geology of the Jackson, Catahoula, and Lower Oakville from Grimes County to Gonzales County, Texas."

[2]District Geologist, Magnolia Petroleum Company, San Antonio, Texas.

[3]Bowling, Leslie, and Wendler, A. P., Detailed study of some beds, commonly known as Catahoula formation, in Fayette County, Texas, with particular reference to their age: Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 526–547, 1933.

[4]Ellisor, A. C., Jackson group of formations in Texas with notes on Frio and Vicksburg: Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 1293–1350, 1933.

[5]Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, pp. 519–818, 1932 [1933].

they are encountered in wells. Subsurface data showing the formations penetrated by several key wells drilled on the principal structures are included for the convenience of the reader. These wells involve only the section between the Catahoula (Miocene?) and Wilcox (Eocene) formations.

It may be of interest to note that downdip to the southeast the upper Yegua and Jackson rocks produce oil and gas at Conroe, Tomball, Raccoon Bend, and Pettus and in most of the fields of the Laredo area. There is also some small production from these strata farther downdip at Humble, South Liberty, and Hull, which are shallow salt domes where the rocks have been uplifted greatly. The downdip equivalents of the Catahoula and Oakville formations of the surface contain numerous producing sands from which production is obtained on many of the Gulf Coast salt domes and other structures.[6]

The old geologic nomenclature is very confusing to the person who is not familiar with the surface sections. In attempting to clarify this confusion, Plate I was prepared. The plate shows in so far as possible the synonymy of the older geologic names as compared with the section described in this paper. The geologic sections accompanying this paper (Pls. III, IV, and V) contain the specific localities of a number of characteristic outcrops. With an ownership map at hand, these outcrops may be readily located by any geologist who is interested in examining the sections in the field.

ACKNOWLEDGMENTS

Acknowledgments are tendered the management of the Magnolia Petroleum Company, including particularly George Edwin Dorsey, Clyde M. Bennett, deceased, and S. A. Thompson for their helpful coöperation. Miss Julia Gardner of the United States Geological Survey has kindly identified macrofossils from several localities, and John R. Sandidge, paleontologist with the Magnolia Petroleum Company, has identified Foraminifera in a number of samples. C. Wythe Cooke, Miss Julia Gardner, H. B. Stenzel, and Henry V. Howe have kindly read the manuscript, but responsibility for the statements contained herein rests entirely with the author unless quoted from other sources. The coöperation of E. H. Sellards

[6]Deussen, Alexander, Oil producing horizons of the Gulf Coast in Texas and Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 18, pp. 500–518, 1934.

of the Bureau of Economic Geology in the publication of the paper is appreciated. Fred E. Joekel assisted greatly, particularly in the preparation of illustrations. The geologic mapping of Fayette County was done in 1930 by L. H. Williams under the author's direction, and his map has been of considerable help in connection with the measurement of the geologic sections of that county shown in the accompanying plates. Barton W. Moore assisted in the original mapping of part of the area covered by Plate VI. W. B. Ferguson of the Sun Oil Company has kindly furnished certain data in Washington County, especially pertaining to the Clay Creek salt dome. The Edgar Tobin Aerial Surveys of San Antonio have kindly furnished the base map for Plate VI.

STRATIGRAPHY

RECENT

ALLUVIUM

A belt of alluvium borders the rivers and principal creeks. The flood plain material adjacent to Brazos River attains a maximum width of about 6 miles within the area mapped. The top of the flood plain of Brazos River is about 30 feet above the normal stage of the river, and the top of the flood plain of Colorado River is about 20 feet above the normal stage of the stream within the area shown on Plate II. Adjacent to Brazos and Colorado rivers the flood plain material is tan to red. This red color is doubtless due in part to the fact that the red Permian rocks of north-central Texas have contributed a considerable amount of the material. However, the color of the alluvium bordering Navasota River and the creeks of the area shown in Plate VI is dark brown to black, the material having been derived from darker-colored rocks closer at hand.

PLEISTOCENE

A discussion of the terrace deposits is not really within the scope of this paper. However, they are briefly mentioned here because they occupy such an important part of Plate VI where their distribution is approximately shown. These deposits were noted only casually in most places but were mapped where the bed rock geology was concealed as, for example, in the southern part of

Brazos County (Pl. VI). Throughout the area shown on the accompanying map, Plate II, there are terrace deposits of at least two ages and possibly more.

HIGH TERRACE DEPOSITS (UVALDE?)

High-level gravels cover portions of the divides between many of the major streams. They conceal the local details of the bed rock geology at a number of places, and in other places they slump down over the lower terrace deposits and obscure the contact of the latter as well as the bed rock formations. These high-level gravels consist mostly of well rounded siliceous materials; chert, quartz, chalcedony, jasper, limestone, and fragments of igneous rock comprise most of the deposits. The boulders and cobbles making up the gravels range from the size of a pea to 6 inches in diameter and are interbedded with coarse sand. The gravel beds range in thickness from a thin veneer of scattered cobbles to a thickness of 30 feet or more. They are well displayed along the Southern Pacific right-of-way and along old (macadam) State highway No. 6 in the southern part of the H. Evans Association, A. Millican Survey, in southern Brazos County, and to the southwest in the E. M. Millican, Wm. Devers, and Walter Southerland surveys. In southern Brazos County these gravels reach an elevation of slightly over 300 feet which is about 100 feet above the flood plain of Brazos River; towards the southwest in Fayette and Gonzales counties they attain an elevation of 450 feet.

Deussen[7] correlates these gravels with the Uvalde gravels to the west, which in Bexar County reach an elevation of 680 feet and in Uvalde County, 970 feet. They probably represent the updip facies of the Reynosa-Lissie deposits of the Gulf Coastal Plain to the southeast.

LOW TERRACE DEPOSITS

Twenty to 30 feet above the alluvial flood plain of Brazos River there are terrace deposits consisting of finer material than the high-level gravels. These lower deposits consist of sand, clay, and a small amount of fine gravel. A terrace along old (macadam) State highway No. 6 (see Pl. VI) between Brazos and Navasota rivers

[7]Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, p. 8, 1924.

is well shown in the southern part of the L. C. Smith and northern part of the Wm. Millican surveys. The station of Nelleva on the Southern Pacific Railroad in the B. B. B. & C. Railroad Survey No. 84 is on this terrace. These deposits generally give rise to a black land soil and probably represent the upstream facies of the Beaumont formation.

Near Pitt's bridge on Brazos River, Dr. Mark Francis collected from these terraces a number of Pleistocene vertebrates which were described by O. P. Hay.[8]

Amyda emoryi?	Bison sp. indet.
Chrysemys belli Gray	Camelops huerfanensis Cragin?
Terrapene impressi n.sp.	Tetrameryx shuleri
T. whitneyi Hay	Equus complicatus
Testudo annae Hay	Anancus gratus
Chlamytherium septentrionale Leidy	Elephas columbi Falconer
Chlamytherium sp.	E. imperator Leidy
Megatherium mirabile	Mammut americanum
Mylodon sp. indet.	M. francisi Hay
Bison latifrons Leidy	M. progenium

Dr. Francis[9] reports that in November, 1934, a cervical vertebra of some large unidentified sloth was found.

EOCENE

CLAIBORNE GROUP

YEGUA FORMATION

The Yegua formation, which is the topmost part of the Claiborne group and on which the Jackson group rests, is not included within the scope of this paper, but a brief description is included in order to complete the geologic section.

---

[8]Hay, O. P., Characteristics of sundry vertebrates: Pan-American Geol., vol. 39, pp. 101–120, pls. 7, 8, 9, 1923.

———, ———, The Pleistocene of the middle region of North America and its vertebrated animals: Carnegie Inst. Washington, Pub. 322a, pp. 3, 18, 61, 89–90, 105, 128, 162, 187, 228, 244–245, 1924

———, ———, Two new Pleistocene mastodons: Jour. Washington Acad. Sci., vol. 16, no. 2, pp. 35–39, 1926.

Cahn, A. R., Chlamytherium septentrionalis, a fossil edentate new to the fauna of Texas: Jour. Mammalogy, vol. 3, pp. 22–24, 1922.

[9]Letter of July 24, 1935.

NAME AND LITERATURE

The name Yegua was proposed by Dumble[10] who divided the Fayette of Penrose[11] into the Yegua below and the Fayette above. (See Pl. I.) The synonymy of the name Yegua has been described recently in considerable detail by Plummer[12] and will not be reviewed in this paper. These are in part the same strata to which the name Cockfield of Veatch[13] has been applied by Ellisor.[14]

LITHOLOGY

The Yegua formation of the northeastern part of the Texas Gulf Coastal Plain consists of sand, sandy shale, and clay. The sands are thinly laminated and highly cross-bedded. In fresh cores from wells the sands of the Yegua are usually brown, but on the weathered outcrop they are largely gray, while the clays grade from chocolate color to tan and gray. There are a number of lignite beds in the Yegua formation, and the formation is more or less characterized by the occurrence of disseminated lignite throughout. The lower part of the formation contains some marine lentils, but none were noted in the upper 100 feet of the formation.

Lithologically the Yegua formation is similar in many respects to the Jackson, but on the whole the Yegua contains less chocolate-colored clays than the Jackson and the weathered outcrop in general has more of a grayish hue. This latter statement is somewhat of a generalization since both the Yegua formation and the Jackson group contain chocolate-colored clay and gray cross-bedded sands. Where the well-developed marine facies of the Caddell formation is present the upper contact of the Yegua formation is easily recognized.

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[10]Dumble, E. T. Report on the brown coal and lignite of Texas; character, formation, occurrence, and fuel uses. Texas Geol. Surv., pp. 148-153, 1892.

[11]Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiary of Texas from Red River to the Rio Grande: Texas Geol. Surv., 1st Ann. Rept. p. 47, 1890.

[12]Plummer, F. B., *op. cit.*, pp. 666-676.

[13]Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Surv. Prof. Paper 46, 422 pp., 1906.

[14]Ellisor, A. C., Correlation of the Claiborne of east Texas with the Claiborne of Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 13, pp. 1335-1346., 1929.

DEPOSITIONAL CONDITIONS[15]

The Yegua strata in this area record a time of terrestrial deposition during which a number of streams flowed across the present area of Yegua outcrop depositing cross-bedded sand, silt, and clay, some of which was derived from a volcanic source. These fluviatile deposits coalesce and interfinger with lignitic sands, clays, and lignites which were deposited in coastal swamps. Horizontally-bedded shales and sands were observed at a number of places and are interpreted as being of probable lacustrine or lagoonal origin.

Deposits of deltaic origin also comprise a considerable portion of the Yegua formation and at a number of places there are steeply dipping foreset beds. Reed and Longnecker[16] described a Yegua delta south of the town of Bryan in Brazos County. This delta shows steeply dipping foreset beds overlain by nearly horizontal topset strata. The delta was subsequently channeled by a river that deposited a considerable accumulation of fluviatile gravel. On the whole, gravel deposits are scarce in the Yegua formation.

During Yegua time the land bordering the coast was subsiding slowly and accumulating terrestrial deposits. However, this subsidence was at no faster rate than the sediments were accumulating since the sea failed to enter this Yegua land surface at any time in most of the areas shown on Plate II.

JACKSON GROUP

NAME AND LITERATURE

Conrad[17] first described the Jackson fauna. He stated that "Col. B. L. C. Wailes discovered a new group of Eocene fossils at Jackson [Mississippi] in which none of the Vicksburg species occur, and of forty species five only are identical with Claiborne

[15]The sedimentation conditions of the several Cenozoic formations have been described by F. B. Plummer in The Geology of Texas, Univ. Texas Bull. 3232, pp. 519–818, 1932 [1933].

[16]Reed, L. C., and Longnecker, O. M., Jr., A Yegua Eocene delta in Brazos County, Texas: Univ. Texas Bull. 2901, pp. 163–174, 1929.

[17]Conrad, T. A., Observations on the Eocene deposit of Jackson, Mississippi, with descriptions of thirty-four new species of shells and corals: Proc., Acad. Nat. Sci. Philadelphia, vol. 7 pp. 257, 1855.

fossils." Jackson has since been used continuously for these upper Eocene strata in Mississippi, Alabama, and Louisiana.[18]

Penrose[19] introduced the name Fayette beds in Texas and included strata from the base of the Yegua to the upper Lagarto. (See Pl. I.) Kennedy[20] also included in the Fayette sands beds from the Yegua to the Lagarto but subsequently included a large part of these strata in his Navasota beds.[21] Dumble[22] then divided the Fayette of Penrose into the Yegua below and the Fayette above. Two years later Dumble[23] further subdivided his upper division or Fayette into Fayette, Frio, Oakville, Lapara, and Lagarto. (See Pl. I.)

Kennedy[24] in describing the Tertiary section east of Brazos River included within the Fayette sands strata from the Wellborn forma-

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[18]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, pp. 128–138, 1860 (Jackson group).

Hopkins, F. V., Second annual report of the geological survey of Louisiana, pp. 7–15, 1871 (Jackson group).

Leich, Otto, A preliminary report upon the hills of Louisiana south of the Vicksburg, Shreveport and Pacific Railroad to Alexandria, Louisiana: Louisiana State Exp. Sta., Geol. Agri. La., pt. 2, pp. 88–91, 1893 (Jackson group).

Dall, W. H., A table of the North American Tertiary formations, correlated with one another and with those of western Europe, with annotations: U. S. Geol. Surv., 18th Ann. Rept., pt. 2, p. 342, 1898 (Jackson stage).

Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Surv., Prof. Paper 46, pp. 39–40, 1906 (Jackson formation).

Lowe, E. N., Mississippi, its geology, geography, soil and mineral resources. Mississippi State Geol. Survey, Bull. 14, pp. 80–85, 1919 (Jackson group).

Cooke, C. W., Correlation of the deposits of Jackson and Vicksburg ages in Mississippi and Alabama: Jour. Washington Acad. Sci., vol. 8, pp. 186–198, 1918 (Jackson formation).

———, ———, Geology of Alabama; the Cenozoic formations: Alabama Geol. Surv., Spec. Rept. 14, pp. 274–278, 1926 (deposits of Jackson age).

Stephenson, L. W., The ground-water resources of Mississippi: U. S. Geol. Surv., Water-Supply Paper 576, p. 53, 1928 (Jackson formation).

Semmes, Douglas, Oil and gas in Alabama. Alabama Geol. Surv., Spec. Rept. 15, pp. 271–275, 1929 (formation of Jackson age).

Moody, C. L., Tertiary history of region of Sabine uplift, Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 15, pp. 542–544, 1931 (Jackson formation).

Howe, H. V., Review of Tertiary stratigraphy of Louisiana. Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 628–632, 1933 (Jackson group).

[19]Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiary of Texas from Red River to the Rio Grande: Texas Geol. Surv., 1st Ann. Rept., pp. 47–50, 1890.

[20]Kennedy, W., A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Surv., 3d Ann. Rept., p. 60, 1892.

[21]Kennedy, W., Report on Grimes, Brazos, and Robertson counties: Texas Geol. Surv., 4th Ann. Rept., pp. 7–14, 1893.

[22]Dumble, E. T., Report on the brown coal and lignite of Texas; character, formation, occurrence, and fuel uses: Texas Geol. Surv., p. 243, 1892.

[23]Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geol., vol. 2, pp. 549–567, 1894.

[24]Kennedy, W., The Eocene Tertiary of Texas east of the Brazos River: Acad. Nat. Sci. Philadelphia, Proc. 1895, pp. 95–99, 1896.

tion to the Oakville formation. Hayes and Kennedy[25] included within the Fayette strata from the Wellborn formation into the Lagarto. Veatch[26] included a large part of the Fayette within the Catahoula. Deussen[27] assigned only the Caddell as far west as central Angelina County to the Jackson and included within the Catahoula all overlying Jackson strata as well as the Caddell southwest of Angelina County. (See Pl. I.)

Dumble[28]subsequently assigned certain strata in the upper part of the Yegua to the Fayette and selected as the type locality for his restricted Fayette, beds of Yegua age exposed on Colorado River northeast of West Point which he assigned to the Claiborne. Deussen[29] used the name Fayette sandstone for the strata between the Catahoula and the Yegua formations and regarded these as of Jackson age.

Dumble[30] later redefined the Fayette but since the limits of his redefined names and his correlations with the east Texas section may not be clear to all readers, the following quotations have been taken from his report.

> In our revised section, the Fayette is limited to the series of beds which is found exposed in the Lipan Hills east of Campbellton. . . . In the separation of the former Fayette of type section into two series, the lower or true Fayette which we still hold to be Claiborne has been called the Lipan beds, and the upper, the Whitsett beds.

Dumble assigned these strata outcropping in the Lipan Hills to the Claiborne on the basis of the following fossils identified by Harris:

Venericardia planicosta	Meretrix trigoneata Lea
Corbula alabamensis, broad form	Meretrix trigoneata var.
Corbula alabamensis var.	Tellina cherokeensis Harris?

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[25]Hayes, C. W., and Kennedy, W., Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol Surv., Bull. 212, 174 pp., colored areal map, 1903.

[26]Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Surv., Prof. Paper 46, map, 1906.

[27]Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Surv., Water-Supply Paper 335, map, 1914.

[28]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, p. 134, 1918.

[29]Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, pp. 84–85, 1924.

[30]Dumble, E. T., A revision of the Texas Tertiary section with special reference to the oil-well geology of the coast region: Bull. Amer. Assoc. Petr. Geol., vol. 8, pp. 431 and 433, 1924.

Spisula praetenuis Con.	Pseudoliva vetusta var. A.
Spisula decisa Con. var.	Cornulina armigera Con.
Meretrix sp.	Crenella cast
Modiolus texanus Gabb	Cerithium sp.

Another article by Dumble[31] discusses the same beds.

The Whitsett beds of Dumble, which he assigned to the Jackson, contain greenish-gray and yellow clays interbedded with yellow, gray, brown, and pink sands with some associated beds of volcanic ash. They are the topmost formation of the Jackson as described in this paper. Dumble apparently confused the position of his Whitsett beds and correlated them with the Caddell as shown by the following statement on pages 433 and 434 of the paper cited.

> A microscopic study shows the presence in surface samples taken from these beds [Whitsett] of a typical Jackson foraminiferal fauna such as is found in the vicinity of Caddell and White City. We consider that the unconformity by overlap of the Whitsett beds upon the Fayette, their lithologic similarity to the east Texas Jackson, and, above all, the identity of their foraminifera with those of the Caddell clays fully warrant our references of them to the Jackson, although the molluscan forms collected along our line of section are not distinctive of this age.

Miss Ellisor[32] who recently discussed the surface and subsurface relationships used the term Jackson group for the strata between the Yegua and Catahoula or Frio formations and divided this group into the Caddell, McElroy, and Whitsett. Plummer[33] pointed out the three-fold classification of Miss Ellisor for northeast Texas and the two-fold classification of Dumble for south Texas. The present paper deals only with the surface outcrop of the Jackson group northeast of Guadalupe River in which area this group is divisible into four mappable formations, the Caddell, Wellborn, Manning, and Whitsett. The three-fold classification of Miss Ellisor is inadequate for surface mapping, and though the author regrets the necessity of using another subdivision, it seems desirable to propose the above mentioned four-fold classification of the Jackson group which is based on field mapping. (See table 1.)

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[31] Dumble, E. T., Geology of southwestern Texas. Trans. Amer. Inst. Min. Eng., vol. 33, pp. 915–987, 1903. This report contains lists of fossils which were studied by G. D. Harris.

[32] Ellisor, A. C., Jackson group of formations in Texas with notes on Frio and Vicksburg. Bull. Amer. Assoc. Petr. Geol., vol. 17, p. 1298, 1933.

[33] Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas, Vol. I, Stratigraphy. Univ. Texas Bull. 3232, p. 685, 1932 [1933].

Table 1. Stratigraphic Section of Formations on Surface.

Period	Group	Formation	Surface thickness in feet	Number	Member	Surface thickness in feet	Lithology
MIOCENE		Oakville		19 18	Middle Oakville (Moulton sandstone at base)	20 to 60	Gray and buff sand, sandstone, and grits, with calcareous matrix and reworked Cretaceous fossils, interbedded with calcareous shales; nonmarine.
				17	Lower Oakville	60 to 100	Gray and buff shales with lenses of calcareous sandstone, containing vertebrate bones locally; some green tuffaceous shales and sandstones in southwestern part of the area.
MIOCENE?		Catahoula	50 to 310	16			Green and gray tuffaceous shales and gray sands; noncalcareous in northeast part of area, containing some calcareous sandstone and sand in Fayette and Gonzales counties; nonmarine throughout.
				15	Dunlap Quarry sandstone	0 to 25	Coarse quartz (rice grain) sandstone and conglomerate, locally quartzitic; grades into tuffaceous sand; not found in southwestern part of area; terrestrial.
				14			Same as 16 above.
				13	Chita sandstone	3 to 25	Same as 15 above.
EOCENE	JACKSON	Whitsett	75 to 132	12		75 to 132	Cross bedded sand and sandstone, interbedded with some tuffaceous shale, with opalized logs and fossil leaves; containing fine sandy tuff beds in Brazos County; mostly non-marine but contains a few marine lentils in Fayette and Gonzales counties.
		Manning	250 to 350	11		0 to 25	Same as 7 but contains some beds similar to 12.
				10	Yuma sandstone	3 to 25	Massive and flaggy sandstone, locally containing fossiliferous marine beds.
				9		25 to 40	Same as 7.
				8	Dilworth sandstone	2 to 22	Massive sandstone, generally marine at top.
				7			Chocolate-colored lignitic clay with interbedded tan sand and sandstone and gray tuffaceous sandstone, with thin beds of lignite; some thin fossiliferous marine beds but mostly nonmarine.
		Wellborn	25 to 150	6	Carlos sandstone	5 to 22	Massive gray sandstone, with impressions of stems, locally semiquartzitic.
				5	Middle Wellborn	10 to 120	Same as 7.
				4	Bedias sandstone	0 to 30	Massive gray sandstone, locally quartzitic; contains marine beds near top at some localities.
		Caddell (Moodys marl)	100 to 200	3			Chocolate-colored shales and sands, locally lignitic; nonmarine beds and interbedded marine glauconitic shales
				2	Basal sandstone	0 to 25	Gray calcareous sandstone, locally with ferruginous concretions and locally fossil-bearing.
	CLAIBORNE	Yegua		1			Lignitic sands, clays, and shales, with thin beds of lignite; mostly nonmarine.

At the surface it is not feasible to use the subdivisions of the Jackson group used in downdip wells because the Foraminifera on which these subdivisions are based are not present at most places on the surface.

In assembling the columnar sections shown as Plates III, IV, and V, the thickness of the separate units of the Jackson group as measured individually on the surface has been used. Because of the rapid thickening of the Jackson group downdip from the outcrop, a well located in the country where the Catahoula, Oakville, and Lagarto formations are at the surface will have an interval of 900 to 1100 feet for the Jackson group.

CADDELL FORMATION (MOODYS MARL)

NAME AND LITERATURE

The name Caddell was first used by Dumble[34] to describe the basal Jackson beds in east Texas. This name was taken from a small town in San Augustine County. Miss Ellisor[35] has used the name Caddell for several years for the basal member of the Jackson, and in Plummer's[36] recent publication this name was adopted.

The glauconitic marl of the Caddell formation is similar in lithology and stratigraphic position to the Moody's Branch green marl of Lowe[37] at Jackson, Mississippi, a name that has subsequently been contracted to Moodys marl. Miss Ellisor[38] states that at the base of the Caddell there is a zone of "*Operculina oliveri*" Cushman which she has traced from Caddell in San Augustine County to Veatch's locality on Sabine River three-quarters of a mile below Robertson's Ferry and from there across Louisiana into the Moodys marl at Jackson, Mississippi.

Since the name Moodys marl has priority perhaps it should be adopted for the basal formation of the Jackson in Texas.

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[34]Dumble, E. T. The geology of east Texas. Univ. Texas Bull. 1869, pp. 177–178, 1918.

[35]Ellisor, A. C. Jackson formation in Texas. Presented at San Antonio meeting of the Society of Economic Paleontologists and Mineralogists, March 1931. This paper was not printed, but a more inclusive paper, presented at the meeting of the American Association of Petroleum Geologists at Houston, March, 1933, has been published under the title "Jackson group of formations in Texas with notes on Byo and Vicksburg." Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 1293–1350, 1933.

[36]Plummer, F. B. Cenozoic systems in Texas. Univ. Texas Bull. 3232, p. 685, 1932 [1933].

[37]Lowe, E. N. Mississippi: its geology, geography, soils and mineral resources. Mississippi Geol. Surv., Bull. 12, pp. 80–82, 1915.

[38]Ellisor, A. C., *op. cit.*, p. 1299.

In Brazos County Dumble[39] apparently confused the position of the Caddell formation because he stated that the Caddell clays overlie the Wellborn which he considered the basal member of the Jackson in that county. The section north of the Koppe bridge, which is recorded below, was referred to the Wellborn by Kelley, one of Dumble's assistants.[40]

Section of a portion of the Caddell formation north of Koppe bridge, Brazos County.[41]

	Thickness *Feet*
Terrace sand and gravel.	
Gray and greenish-gray clay slightly sandy containing disseminated glauconite and thin concretionary beds; *Textularia dibollensis* Cushman and Applin rare	7
Iron concretion	0.5
Dark gray to gray-green unctuous clay; fossil imprints; *Textularia dibollensis* Cushman and Applin rare	5.5
Blue-gray to green-gray clay; fossil imprints; few gray lenticular sand laminations especially in the top	4.75
Gray sandy clay with pipes of shipworms throughout encrusted with lime; silicified logs in upper half; logs also bored by shipworms; *Textularia dibollensis* Cushman and Applin, *Quinqueloculina* sp.	5
Light greenish-gray cross-bedded sand with hard silicified 6-inch bed; manganese-stained bed at top containing large pipes; makes prominent bench	4.5
Like above but cross-bedded and in thinner laminations; some 1-inch thick black sand stringers at top	4
Light gray-green soft clayey sand	3
Total exposed	34.25

Brazos River level, June 6, 1933.

Dumble referred to a section 2 miles south (downdip) from the old Batte Ferry as being probably Caddell. However, the top of the Wellborn formation is exposed at the old Batte Ferry, and the beds 2 miles down Brazos River from the ferry (*i.e.*, downdip) belong to the Manning formation. Strata on Brazos River 5 miles west of Millican were also erroneously referred to the Caddell by Dumble.

[39]Dumble, E. T., *op. cit.*, p. 148 and second section on p. 151.

[40]Dumble, E. T., *op. cit.*, geologic section at top of p. 152.

[41]Measured in company with H. B. Stenzel. Micropaleontologic examination of samples by John R. Sandidge.

LITHOLOGY[42]

Dumble pointed out that in the vicinity of Caddell, a small town in San Augustine County, there are green clays and sands, calcareous fossiliferous concretions, and chocolate-colored clays. Although the region east of Trinity River is not under consideration in this paper, the writer has mapped this unit over a considerable area between Neches and Sabine rivers and has seen a great many cores of the Caddell formation taken from wells. The writer's observation is that the lithology of this unit in Angelina and adjoining counties is quite different from that found on the surface in the country southwest of Trinity River.

At fresh exposures in Angelina County and in cores from wells the Caddell formation is essentially a fossiliferous glauconitic marl. White fragile shells abound throughout and disseminated glauconite grains give the Caddell formation a green color. There is at least one very hard fossiliferous glauconitic calcareous sandstone which occurs about 30 feet above the base of the formation. The Caddell formation weathers to a red or red-brown color, and the fossils are generally preserved only as casts. Even where fresh exposures are wanting in the heavily timbered country east of Trinity River, the red and red-brown soil which contrasts sharply with the overlying and underlying gray and tan soils makes it an easily mappable unit.

From western Walker County to Gonzales County the Caddell formation consists mostly of gray and tan cross-bedded sands and gray and chocolate-colored clays.

A sample of sandstone collected about 750 feet east of the west corner of F. C. Reid 927-acre tract, Charles Mason Survey, Gonzales County, from near the base of the Caddell formation was sent to C. S. Ross[43] of the United States Geological Survey who wrote as follows:

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[42]Typical exposures of the Caddell formation occur at the following localities: at the Koppe bridge across Brazos River, 3.8 miles S. 60° W. of Wellborn, Brazos County (*Textularia dibollensis* Cushman and Applin present); along the Navasota-Madisonville State highway No. 90, north of Bedias, in the west part of the T. P. Plaster Survey, Grimes County, along the Somerville-Caldwell highway about one-half mile northwest of Lyons on the Aug. Schoppe Sr. 106.5-acre tract, J. Foster Survey, Burleson County; along the Flatonia-Cistern road 3 miles S. 62° W. of Floy on the Otto Steinhauser 69.3-acre tract, Jas. Parrot Survey, Fayette County; along the Gonzales-Moulton road about 6 miles east of Gonzales and 0.4 mile southeast of Unity Church on the Bud Bartsch 200-acre tract, I. S. Butler Survey (*Textularia dibollensis* Cushman and Applin present).

[43]Letter of November 27, 1934.

Composed of a divergent group of minerals. Contains much detrital material, comprising quartz, microcline, and perhaps part of plagioclase. Associated with this is glauconite. Tuff fragments that were originally glassy but now altered to bentonite and a few altered rock grains are also included. The plagioclase may be derived from the volcanic materials rather than the detrital ones.

Some of the sands and clays contain lignitic material so that in many places the Caddell formation is not easily separable from the underlying Yegua formation. The Caddell formation also contains calcareous sandstone and aragonite concretions, the latter being especially characteristic of the basal part of the formation in Fayette County. Within the Caddell formation in the area shown on Plate II are lenticular glauconitic clay zones. These glauconitic clay beds at many places contain fossil casts, but casts also occur locally in some of the chocolate-colored clay beds which are very similar lithologically to the nonmarine clays in the Wellborn and Manning formations. Fossil casts have also been found in the ferruginous concretions which occur in the sands of the Caddell formation. A good exposure of fossiliferous brown sandy clay is noted in a cut along the Gonzales-Dilworth road where the latter crosses the Bud Bartsch 200-acre tract, J. S. Butler Survey. This zone is 65 feet below the base of the Wellborn sandstone. (See section I, Pl. V.)

STRATIGRAPHIC RELATIONS AND THICKNESS

East of Trinity River the glauconitic marl of the Caddell formation rests on the lignitic sands of the Yegua formation giving rise to a sharp contact. In Brazos, Grimes, and Burleson counties there is a gray cross-bedded sand ranging from 10 to 25 feet in thickness at the base of the Caddell formation which contains lenses of ferruginous sand with fossil casts. (See map, Pl. VI.) This sand is regarded as the base of the Caddell formation as shown in the columnar sections 1, 2, 3, and 5, Plate III, and referred to as the basal sandstone in table 1.

In northern Fayette County at approximately the same stratigraphic position a similar basal sand is present, but south of Colorado River at the horizon mapped as the base of the Caddell formation there is a calcareous sandstone containing aragonite concretions. This sandstone produces numerous disseminated aragonite crystals on weathering.[11]

[11]Typical exposures of the basal Caddell sandstone are present at the following localities: along the road on west side of L. F. Mixes 18.5-acre tract, J. J. Martin Survey, 3.8 miles

Near the Gonzales-Fayette County line this calcareous, aragonite-bearing sandstone was not found, and the contact is drawn at the base of a more or less persistent clay bed containing calcareous concretions.[15] The strata below these concretions are lithologically similar to the Yegua formation. In the northeast part of Gonzales County the contact of the Caddell and Yegua formations is drawn at the base of a gray sandstone below a glauconitic zone which contains fossiliferous ironstone concretions. Both beds are exposed along the east bank of Five Mile Creek near the southwest line of the L. Mallett Survey, 0.6 mile northwest of the east corner. This sandstone bed is about 125 feet below the base of the Wellborn sandstone. (See section E, Pl. V.) The base of the Caddell in the east part of Gonzales County is considered to be in the northwest part of the Charles Mason Survey, about 6 miles N. 82° E. of Gonzales. The formation appears to average about 150 feet in thickness in Gonzales County. (See sections D, E, and I, Pl. V.)

Surface data indicate that the Caddell formation is conformable on the Yegua formation. No persistent beds were found on which elevations could be run, and the dip is therefore assumed to be the same as that of the overlying Wellborn formation which varies from 66 to 104 feet per mile. On this basis the thicknesses as shown in Plates III, IV and V have been calculated and found to range from 110 to 200 feet.

PALEONTOLOGY AND AGE

Microscopic examination of the foraminifera found in the Caddell clay shows that it is characterized by *Textularia dibollensis* Cushman and Applin, a fact which has previously been pointed out

N. 15° W. of Carlos station, Grimes County, along the road south of the south corner of the J. M. Higgins et al, 132 acre tract, T. Carruthers Survey 1.7 miles N. 26° E. of Wellborn Brazos County; exposed at low water level about 500 feet north of the Koppe bridge on the east bank of Brazos River, 3.8 miles S. 60° W. of Wellborn Brazos County, at the east corner of the A. Schoppe 286.5 acre tract, J. Foster Survey, on the Caldwell Somerville road 1 mile N. 51° W. of Lyons, Burleson County, near the south bank of Buckners Creek along the road near the north line of the M. L. Pittman 97-acre tract, M. Muldoon Survey 1.8 miles N. 40° W. of Muldoon station, Fayette County, along the road on the south bank of Live Oak Creek on the W. J. Bochnke 392.5 acre tract, F. A. Bettinger Survey 2.5 miles S. 78° W. of Muldoon station Fayette County.

[15] Exposed along the old Flatonia Waelder road in the northeast part of the Dan Sutton 112.5 acre tract northeast part of J. Gibson Survey 5.3 miles N. 84° W. of Flatonia Fayette County. (See section C, Pl. V.)

by Applin, Ellisor, and Kniker[46] and more recently by Miss Ellisor.[47] The section exposed north of the Koppe bridge on Brazos River, described on page 18, shows *Textularia dibollensis* Cushman and Applin. This foraminifer has also been found in several other places.

Six miles east of Gonzales on the Gonzales-Dilworth road where the latter crosses the Bud Bartsch 100-acre tract, J. S. Butler Survey, Sandidge[48] reports *Textularia hockleyensis* Cushman and Applin, *Textularia dibollensis* Cushman and Applin, and *Ammobaculites* sp. It has not been established on the surface whether or not the *Textularia dibollensis* zone ranges upward into the overlying Wellborn formation or if it extends below the sand mapped as the base of the Caddell formation.

Ball[49] refers to a locality on the Robert Stevenson League about 1.5 miles north of Wellborn station, Brazos County, and about 75 yards north of milepost 90 on the H. & T. C. (Southern Pacific) Railroad. This locality is in a steep-walled ravine west of the old (macadam) State highway No. 6 and the contact of the Bedias sandstone and the Caddell formation is at this place (see Pl. VI). Fossil leaves occur in the Caddell formation just below the Bedias sandstone, which is not well developed here. Ball identified the following species from the locality.

Hicoria jacksoniana Berry
Combretum petraflumense Berry

DEPOSITIONAL CONDITIONS

From eastern Trinity County eastward to Sabine River and into Louisiana, the Caddell formation (Moodys marl) is represented by abundantly fossiliferous marl. These strata were doubtless deposited in a shallow water marine (neritic) environment.

In that region the sea encroached on the nonmarine Yegua deposits as shown by the sharp contact between the continental

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[46]Applin, E. R., Ellisor, A. C., and Kniker, H. T., Subsurface stratigraphy of the Coastal Plain of Texas and Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 9, pp. 79–122, 1925.

[47]Ellisor, A. C., Jackson group of formations in Texas with notes on Frio and Vicksburg: Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 1298–1303, 1933.

[48]Sandidge, J. R., personal communication.

[49]Ball, O. M., A contribution to the paleobotany of the Eocene of Texas: Texas Agri. Mech. Coll., Bull., ser. 4, vol. 2, no. 5, p. 132, 1931.

Yegua strata and the overlying marine Caddell strata in the Angelina River valley and country to the east. However, westward from Trinity County and throughout the area shown on the accompanying map (Pl. II) the Caddell deposits contain less marine material and were accumulated under fluviatile, palustrine, littoral and in small part under marine conditions with an interfingering and interlayering of these types of deposits.

During Caddell time the area of the present surface outcrop shown on Plate II was very close to strand line level, and there were oscillations and retreats of the sea causing shallow water marine layers to be interbedded with the continental deposits as contrasted with northeast Texas where shallow water marine conditions prevailed almost uninterruptedly throughout Caddell time.

WELLBORN FORMATION

NAME AND LITERATURE

The Wellborn was described by Kennedy[50] as follows:

> These sandstones, with their accompanying gray sands, although here tentatively denominated the Wellborn beds, belong to, and help to form a part of, the series of gray sands and sandstones extending across the state from the Neches River in Polk County as far west as Sunnyside church, in Lee County.

He referred to the outcrops of these sandstones southwest of Wellborn station, Brazos County, in the Sam Davidson and James Hope surveys and northeastward in the R. Stevenson Survey. The Wellborn formation as described in this paper crosses these surveys.

Dumble[51] describes the Wellborn beds in the Brazos County localities as given by Kennedy and reports that Kelley, one of his assistants, regards the base of these beds as occurring in a bluff just north of the Koppe bridge, Brazos County. The beds exposed at the Koppe bridge bluff as shown in section 3, Plate III, and in the section on page 18 are Caddell and below the Wellborn formation as used by Kennedy and defined in this paper.

Dumble[52] stated that the Wellborn formation in Grimes County narrows and occurs only in isolated patches, but as a matter of

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[50]Kennedy, W., Report on Grimes, Brazos, and Robertson counties. Texas Geol. Surv., 4th Ann. Rept., p. 45, 1893.

[51]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, pp. 149–151, 1918.

[52]Dumble, E. T., *op. cit.*

fact the outcrop of the Wellborn in that county was found to be wider than in Brazos County, due in part at least to the somewhat flatter dip.

The sandstone south of the station of Manning (Carlos? sandstone of this paper) is referred to as the Wellborn by Ellisor,[53] and the strata below it and above the Caddell formation in Angelina County, she designated Wooley's Bluff because she found a marine fauna at some levels within this interval.

In the writer's opinion these beds below the sandstone at Manning which contain marine lentils and which have been designated Wooley's Bluff represent a marine facies within the Wellborn formation and the name Wellborn is applicable to them. The Wooley's Bluff fauna was not found west of Neches River, and Miss Ellisor therefore states that "west of the Neches River the Wooley's Bluff clays gradually disappear and the Wellborn rests unconformably on the Caddell." No field evidence in support of this supposed unconformity is presented by her, and in mapping the area shown on Plate II of this paper, no evidence of an unconformity was found at the base of the Carlos or Bedias sandstones at any place.

The Carlos sandstone of this paper is approximately equivalent to the Wellborn as described by Miss Ellisor,[54] and consequently her map[55] shows the outcrop of the Wellborn formation considerably at variance with the accompanying map of this paper (Pl. II). For example, from a point south of Wellborn station she refers all of the Jackson strata to the northwest (*i.e.*, updip) to the Caddell formation, whereas the Wellborn formation of this author has an outcrop over a mile in width extending northwestward from a point about one-half of a mile southeast of Wellborn station. (See section 3, Pl. III.) Her map includes within the Caddell formation, strata from which Kennedy[56] collected fossils in the Williams quarry (see section 3, Pl. III) that were included within the Wellborn by him in his original description.

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[53]Ellisor, A. C., *op. cit.*, p. 1307
[54]Ellisor, A. C., *op. cit.*, p. 1306
[55]Ellisor, A. C., *op. cit.*, p. 1295
[56]Kennedy, W., *op. cit.*, p. 13
Dumble, E. T., *op. cit.*, pp. 149–151

It is apparent from Kennedy's descriptions that the Wellborn formation must include the sandstone exposed southeast of Wellborn station (Carlos sandstone) and the Bedias sandstone exposed in the Williams quarry.

The Wellborn formation is divisible into three mappable units: (1) the Bedias sandstone at the base; (2) a nameless middle member consisting largely of shale, sands, clay, and sandy shale; and (3) the Carlos sandstone at the top. Below is a complete section of the Wellborn formation measured in Lee County. However, the middle member at this locality contains more sand than most of the sections to the northeast.

Section measured across the Loving 105-acre tract in the southwest corner of the Claiborne Lawrence Survey, Lee County. Equivalent of Section 6, Plates III and IV. Instrument work by R. C. Briggs.

	Thickness *Feet*
Carlos sandstone:	
Irregularly weathered gray hard to semi-quartzitic sandstone; forming a cuesta; top at the southeast corner of the Loving tract	12 ±
Middle Wellborn:	
Soft gray sand and some interbedded sandstone, partially cross-bedded and bentonitic; more soft sand at top	26 ±
Mostly chocolate-colored lignitic clay, but containing a few sand lenses; partially concealed	58
Chocolate-colored and gray fissile lignitic shale, containing several beds of hard sandstone 1 to 3 inches thick	102 ±
Bedias sandstone:	
Gray sandstone, containing dark brownish-black specks; exposed along road which is southwest line of Loving tract and southwest line of C. Lawrence Survey	3
Total Wellborn formation	117 ±

The entire section, including the Bedias sandstone, the middle member, and the Carlos sandstone, is displayed along the east-west road which forms the south line of the Ed Branecky 125-acre tract and the E. B. Kennon 100-acre tract, Prosper Hope Survey, about 5 miles S. 75° W. from Flatonia. (See section 11, Pl. III and section D, Pl. V.) Southwestward from this point the three-fold division of the Wellborn formation is indeterminate.

BEDIAS SANDSTONE MEMBER

Name.—The basal sandstone of the Wellborn formation is here named the Bedias sandstone for the town of Bedias in northern Grimes County in the vicinity of which it is well exposed.

Lithology.—The Bedias sandstone consisting of an upper hard layer with soft sand below is present over much of the area shown in Plate II but is better developed in Grimes and Brazos counties.[37] The sandstone is almost continuous across Grimes and Brazos counties, but in Burleson County between the Gulf Coast and Santa Fe Railroad and Brazos River it is poorly developed or absent. It may be traced almost continuously across Lee County with the exception of the divide area in the vicinity of the Southern Pacific Railroad, where it is covered with gravel. South of Warda in Fayette County it is not well developed but was located at several places.

Throughout the area shown on Plate II the Bedias sandstone is gray, medium grained, and contains ashy material throughout. The topmost massive beds where present break with a conchoidal fracture and vary from hard sandstone to quartzite. Small black specks probably representing ferro-magnesian minerals are a characteristic of this phase. Where this upper hard phase is sufficiently thick it forms a tree-covered cuesta in Grimes and Brazos counties.

At the top of the Bedias sandstone at the type locality there are massive semi-quartzitic beds attaining a maximum thickness of 10 feet and averaging about 5 feet. These beds have been quarried at a number of localities for house foundations and chimneys. They are well exposed at the following localities: along the center of the east line of H. L. Perkins land in the southeast corner of the James W. Panky Survey; 0.8 mile south of Bedias on State highway No. 90, for about one-half mile; on the old Bedias-Anderson road

[37]Typical exposures of the Bedias sandstone occur at the following localities: along Madisonville-Navasota State highway No. 90, 1 mile south of Bedias, Grimes County; 2.4 miles N. 30° W of Carlos station along the south line of the P. E. Smith 139-acre tract, W. Johnson Survey, Grimes County; 0.9 mile N 80° W. of Wellborn station at the Pleasant Hill Church near the west corner of the A. McMahon Survey, Brazos County, and southwestward across the D. C. Giddings 1530-acre tract, J. Hope Survey; 1.7 miles S. 23° W. of Lyons in the north corner of Susan Scott et al 309-acre tract, James Craft Survey, Burleson County, and southwestward across the northern part of this survey; 3.7 miles N. 10° W. of Ledbetter along the northwest line of the A. Jones Survey, Lee County; at Warda, Fayette County; 0.07 mile east of west line of E. B. Kennon 100-acre tract, Prospect Hope Survey, 5 miles S. 75° W. of Flatonia, Gonzales County.

along the line between the David Jarvis and T. Y. Gilbert surveys in the northwest part of the latter survey. Southeast and east of Bedias this upper phase of the Bedias is not so well represented.

Below the massive phase in the vicinity of Bedias there are from 10 to 20 feet of soft medium-grained cross-bedded light tan sand locally having a greenish-gray tint. Near the type locality this lower phase is well displayed at the following places: along the old Bedias-Anderson road at the northeast corner of the David Jarvis Survey; on the Bedias-Red Top road at the east end of the town of Bedias, 0.1 mile south of the intersection of the east line of the D. S. Stone Survey and the southwest line of the T. P. Plaster Survey.

Stratigraphic relations and thickness.—The upper hard phase and lower soft phase of the Bedias sandstone attain a maximum thickness of 30 feet in Grimes County. It is conformable with the underlying Caddell formation. In parts of Fayette and eastern Burleson counties it grades laterally into chocolate-colored shale which is identical with some of the shale in the Caddell formation. Where this condition obtains it is impossible to map the Wellborn and Caddell contact exactly.

The regional dip of the Bedias sandstone is approximately the same as that of the Carlos sandstone and varies from 66 to 112 feet per mile with an average of 90 feet per mile, and the thickness varies from 0 to 30 feet. (See Pl. III.) In the northeastern part of the area the dip is in general less than in the southwestern part.

Paleontology and age.—Within or at the top of the upper hard phase of the Bedias sandstone there is at a number of places a zone of white sandstone several inches thick consisting of platy layers that contain fossils. This platy bed is present at the top of the Bedias sandstone and contains fossils 0.9 mile N. 80° W. of Wellborn at the northwest corner of the A. McMahon Survey. Kennedy[58] collected from this same sandstone in the now abandoned Dr. Williams quarry on the Robert Stevenson Survey in Brazos County. This quarry is located about 2.4 miles N. 45° E. of Wellborn station in

[58]Kennedy, W., Report on Grimes, Brazos, and Robertson counties: Texas Geol. Surv., 4th Ann. Rept., p. 46, 1893

———, ———, The Eocene Tertiary of Texas east of the Brazos River: Acad Nat. Sci. Philadelphia, Proc. 1895, p. 97, 1896.

There are some differences in the names of some of the forms as given in the two reports. The list is taken from the 1895 report because it probably represents Harris' latest identifications.

the southwest part of the P. L. Brown 330-acre tract. G. D. Harris identified the following species from Kennedy's collection:

Bulimella kellogii	Corbula alabamensis Lea
Pleurotoma sp.	Siliqua simondsi n. sp. Harris
Cancellaria penrosii n. sp. Harris	Venericardia planicosta Lamarck
Yoldia claibornensis Conrad	Cytherea bastropensis Harris
Mactra sp.	Turritella sp.

A collection was made from this same sandstone 5 miles S. 75° W. from Flatonia along the road which is the south line of the E. B. Kennon 100-acre tract, northwest part of the Prosper Hope Survey, Gonzales County (section 11, Pls. III, IV). Miss Gardner[59] identified the following forms in this collection:

Leda? sp. indet.	Indeterminate bivalves
Venericardia sp. indet.	Opisthobranches
Phacoides (Parvilucina) sp. indet.	Mazzalina oweni Dall
Tellina sp. indet.	Turritella sp. cf. T. arenicola Conrad
Spisula n. sp.	Fish scales
Corbula sp. indet.	

Age determination: Upper Jackson (Eocene).

Depositional conditions.—The Bedias sandstone probably represents a beach or littoral deposit of a transgressive sea with marine beds at the top. The lower part which consists of soft cross-bedded sands indicates that it has been subjected to considerable current action. The upper layers which contain marine shells show that this part was deposited under shallow marine conditions. Its absence in some places and gradation into palustrine and fluviatile sediments at other places indicate that there were probably bays and estuaries entering into the sea which prevented the deposition of this sand as a continuous deposit or that channels were cut through it after it was deposited.

MIDDLE WELLBORN MEMBER

Lithology.—Between the Bedias sandstone and the Carlos sandstone there is a member which consists largely of chocolate-colored shales containing disseminated lignite. Interbedded with these shales are also hard beds of sandstone and soft cross-bedded bentonitic sand and sandy shale. (See section on p. 25.)

[59]Gardner, Julia, personal communication, October 7, 1953.

Overlying the Bedias sandstone in most of Grimes, Brazos, and parts of Burleson and Lee counties there are 15 to 25 feet of beds consisting of flaggy sandstone interlaminated with chocolate-colored shale. The platy sandstone layers are from one-eighth to one-half inch thick and the intervening shale layers are from 1 to 6 inches thick.[60] At localities where the Bedias sandstone is soft and exposures are few these overlying beds where present serve as a fair accessory marker in mapping. These flaggy beds grade laterally into shale and at some places they grade into the underlying Bedias sandstone.

Locally this middle member of the Wellborn formation contains hard ledges of sandstone, some of which are continuous for several miles. From 20 to 50 feet above the Bedias sandstone in the vicinity of Bedias and elsewhere in the area there is a sandstone horizon which is not to be confused with the Bedias sandstone or the above mentioned flaggy beds overlying it. One and three-tenths miles south of Bedias and 0.1 mile east of State highway No. 90 on a secondary road along the north line of L. O. Barnes 265-acre tract, T. Y. Gilbert Survey, there is a zone about 20 feet above the Bedias consisting of interbedded flaggy sandstone and shale. (See section 1, Pls. III and IV.) The same zone is exposed along the Bedias-Red Top road, 0.95 mile S. 38° E. of Bedias near the south corner of the T. P. Plaster Survey. Northeast of this last locality along the strike on the southeast line of the T. P. Plaster Survey more massive beds appear in this horizon, and the interval to the Bedias sandstone increases. Good exposures of two sandstones are found along the road at 1.4 and at 1.7 miles N. 30° W. of Carlos, Grimes County (see section 2, Pls. III and IV) along the line between the Daniel Horton and Philip Goodbread surveys; these same beds though not continuous as hard ledges may be traced northeastward for several miles. They consist of hard, somewhat argillaceous and bentonitic sandstone but locally grade into soft cross-bedded bentonitic sand and shale. Southwestward in Brazos County the middle Wellborn member consists mostly of chocolate-colored shale and soft cross-bedded lenticular brown lignitic sand. In

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[60]Good exposures of these beds are found along the road N. 26° W., 2 miles from Carlos, Grimes County, in the north part of the D. Horton Survey and southeast part of the W. Johnson Survey; along the road near the northwest corner of the A. McMahon Survey, 0.8 mile N. 70° W. of Wellborn station, Brazos County.

southeastern Lee County there are sandstones present between the Bedias and Carlos sandstone at a number of localities, one being along the west line of the J. M. Galvin Survey. In the northeast part of Lee County, in the east corner of the H. Best Survey, sands and sandstones make up a considerable part of the section between the Bedias and Carlos sandstones as shown by the following section, as well as by the section on page 25.

Section measured along the road through the center of the R. Carter 181-acre tract, H. Best Survey, northeast Lee County. Instrument work by R. C. Briggs, September 9, 1931.

	Thickness *Feet*
Carlos sandstone:	
Massive irregularly weathered hard sandstone; top of Carlos member	3
Middle Wellborn:	
Soft gray sand interbedded with tan sand and gray shales, the latter containing thin beds of flaggy sandstone; some poorly preserved fossil casts in the flags	12
Hard cross-bedded semi-quartzitic sandstone	1
Cross-bedded, gray and tan sandstone grading into soft sand in the lower part	7
Soft gray and tan sand without flags; lower part fractured	8
Total measured	31
Chocolate-colored lignitic shales.	

Stratigraphic relations and thickness.—The middle member of the Wellborn formation is conformable with the underlying Bedias sandstone. From Grimes County to northwestern Washington County the middle member of the Wellborn is from 80 to 120 feet thick,[61] but southwestward across Lee County into Fayette County this member thins from 75 to 20 feet, and in northern Gonzales County the entire Wellborn formation, including the Bedias sandstone, the middle member, and the Carlos sandstone, is locally only 20 feet thick. Because the entire Wellborn is composed mostly of sand and sandy shale, it is difficult to locate a contact between the Bedias sandstone and the middle member, but in general the top of the Carlos sandstone is easily found.

[61]The thicknesses of this member are calculated using the same dips as the Bedias or Carlos sandstones.

Depositional conditions.—The sands, clays, and sandy shales comprising the middle part of the Wellborn formation indicate that these beds were deposited under a combination of palustrine, fluviatile, and probably littoral conditions. The presence of lignitic material together with the lenticular and cross-bedded character of the sands point to a continental environment. At some places steeply dipping beds resembling foreset delta deposits were observed. Locally there are evenly bedded shales with thin partings of sandstone flags a fraction of an inch thick without cross-bedding. This suggests that at least some of the strata in the middle Wellborn were deposited in lagoonal or lacustrine environments.

CARLOS SANDSTONE

Name.—Carlos sandstone is here introduced for the sandstone member at the top of the Wellborn formation. It is well exposed along the Southern Pacific Railroad right-of-way, now abandoned, 0.25 mile north of Carlos station in Grimes County.[62]

Lithology.—The Carlos sandstone is the most persistent bed in the lower part of the Jackson formation and is represented by an almost continuous outcrop across the area mapped. However, locally in southern Fayette County it was not found. This sandstone is gray to white and more argillaceous than the Bedias sandstone. On the weathered surface it contains a mass of pipes, oriented in all directions, which resemble impressions of fossilized vegetable matter which may represent stems of sea weeds. (See Pl. VIII-A.) The fresh exposures of the rock contain fragments of disseminated lignitized wood and the individual pipes generally contain wood impressions. On the whole the Carlos sandstone is not as hard as the Bedias sandstone and generally breaks with a splintery fracture

[62]Other representative exposures of this bed are found at the following localities: northeast part of J. Schroeder Survey, 3.2 miles S. 13° E. of Bedias, Grimes County; along the new (concrete) Navasota-Bryan State highway No. 6 where it crosses the east line of the A. Babille Survey, 2.9 miles N 60° E of Wellborn, Brazos County; along the old (macadam) Navasota-Bryan State highway No. 6, 0.5 mile southeast of Wellborn station; along the Wellborn-Somerville road on southeast line of J Hope Survey, 1.4 miles S. 32° W. of Wellborn, Brazos County, along the road which is the southwest line of the Somerville Development and Improvement Company 646.5-acre tract, southwest part of O. Perry Survey, 2.1 miles S. 8° W. of Lyons, Burleson County; extending for 2.5 miles along the road which runs along the northwest line of the B. M. Hatfield Survey, Lee County, 6.4 miles N. 23° E. of Ledbetter; along the La Grange-Giddings road, 1 1 miles S. 10° E. of Warda, Fayette County, at Muldoon station, Fayette County; 1.8 miles S. 75° W. of Flatonia along the road near the southwest corner of the Ed Bianecky 125-acre tract, P. Hope Survey, Gonzales County.

instead of the conchoidal fracture which is characteristic of the Bedias sandstone. However, at some places, notably along the outcrop in parts of Fayette County, the top of the Carlos sandstone is harder and semiquartzitic so that it resembles certain phases of the Bedias sandstone.

Stratigraphic relations and thickness.—The Carlos sandstone rests conformably on the middle shale member of the Wellborn formation. The thickness (see Pls. III and IV) varies from 5 to 22 feet. In general the upper layers of the Carlos sandstone are harder. Below it grades into softer sand and finally into chocolate-colored shale of the middle member of the Wellborn formation.

The dip of the Carlos sandstone on the outcrop varies from 66 to 112 feet per mile and averages 90 feet. In the vicinity of the Brenham-Somerville State highway No. 36 the dip was found to be 130 feet per mile, but in this area the dip is abnormally steep due to the proximity of the Clay Creek salt dome.

Depositional conditions.—The environmental conditions under which the Carlos sandstone was deposited are not easily explained. Its widespread distribution and continuity suggests a marine deposit, but the general absence of marine shells argues against a marine environment, and the presence of many stem impressions which occur in this sandstone suggests that it was deposited in very shallow water, perhaps in a lagoon which supported the growth of eel grass, reeds, and other small vegetation. No logs or lignitic material other than stem impressions are present in this sandstone. The cross-bedded character locally suggests current action of some type, perhaps from waves.

MANNING FORMATION

NAME AND LITERATURE

Dumble[63] applied the name Manning to the Jackson strata above the Caddell clays in east Texas, and Miss Ellisor[64] restricted the Manning beds to the strata between the top of her Wellborn and the top of the Dilworth sand. (See Pl. I.) Unfortunately the town of Manning in Angelina County is located on the Carlos? sandstone which is the topmost member of the Wellborn formation. It might

[63]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, p. 176, 1918.

[64]Ellisor, A. C., Jackson group of formations in Texas with notes on Frio and Vicksburg: Bull. Amer. Assoc. Petr. Geol., vol. 17, p. 1307, 1933.

be desirable to abandon this name, but in this report the name Manning is retained for those beds between the top of the Wellborn formation and the bottom of the Whitsett formation.

It does not seem appropriate to use the name McElroy formation for these strata between the Wellborn and Whitsett formations because Miss Ellisor includes the Wooley's Bluff clays, Wellborn sands, and Manning beds in the McElroy. Also in paleontological reports on wells, the name McElroy has come to be almost synonymous with the *Textularia hockleyensis* zone but, as Miss Ellisor points out, this foraminifer ranges up into the uppermost Jackson strata.

LITHOLOGY

Overlying the Wellborn formation there are interbedded clays, shales, and sands which extend across the entire area mapped. In the northeastern part of this area from Grimes County to Fayette County the Manning formation consists of chocolate-colored lignitic clays interbedded with discontinuous lenses of tan and gray cross-bedded sand most of which are lignitic.[65] The sands in some places are ochre-colored due to limonitic stain in them. Tracing these rocks to the southwest it is found that the proportion of chocolate-colored clay decreases and that the proportion of soft cross-bedded tuffaceous sand occurring as lenses in the chocolate-colored lignitic clays increases. Although these sands make up a small part of the section in Grimes and Brazos counties they occupy at least 50 per cent of the formation in southern Fayette and northeastern Gonzales counties. These sands contain some bentonitic clay and sandy clay. (See Pl. VIII-C.) In Brazos and Grimes counties there are several thin beds of white to gray clay. A sample from one such bed was collected 3 miles N. 70° W. of Millican in the P. Millican Survey along the old (macadam) State highway No. 6. C. S. Ross of the

[65]Typical exposures of the chocolate-colored clay phase of the Manning occur at the following localities: along the Bedias-Red Top road across the P. Dixon, H. T. & B. Railroad Company, and north part of F. M. Davis surveys; along the old (macadam) Bryan-Navasota State highway No. 6 in the B. B. B. & C. Railroad Company, B. McGregor, J. C. Stuteville, and south part of Samuel Davidson surveys, Brazos County; on the L. C. Moses, W. A. Higgins, E. Cooper, and south part of B. M. Hatfield surveys, southwestern Washington County; east of Warda in the Thos. Green, S. Sheldon, and San Antonio Ditch Company surveys, Fayette County; west of Flatonia on the old Flatonia-Waelder road in the south part of the W. A. Matthews Survey, Fayette County; west of Moulton along the Moulton-Gonzales road in the west part of the John A. Huesser and north part of the Isaac D. Bradley surveys.

United States Geological Survey examined the sample and advised that it was "very fine-grained and apparently pure kaolinitic clay."

Where these lenses of gray tuffaceous sands occur in the top of the Manning formation and the Dilworth sandstone is absent as in parts of Washington, Fayette, and Gonzales counties, it is difficult to locate the base of the Whitsett formation exactly, but at most places in Fayette and northern Gonzales counties it is marked by a few feet of chocolate-colored shale. The shale is only 5 to 10 feet thick in some places.

There are several persistent sandstone beds in the Manning formation which are described below.

DILWORTH SANDSTONE MEMBER

Three-quarters of a mile southeast of Dilworth, Gonzales County, extending across the E. Kramling 50-acre tract, Wm. Green 144-acre tract, and Jno. Sewfera 105-acre tract in the George Blair Survey, there is a persistent sandstone ledge to which Miss Ellisor[66] has applied the name Dilworth sand.

In Grimes and Brazos counties there is a very persistent sandstone bed from 50 to 70 feet below the Whitsett formation which was used extensively in mapping structure through Grimes, Brazos, and eastern Washington counties. This sandstone was not found in western Washington County and in most of Fayette County. On the basis of stratigraphic position and interval to the base of the Catahoula formation, this sandstone has been tentatively correlated with the Dilworth sandstone of Miss Ellisor in Gonzales County though it is recognized that the sandstone designated as Yuma may be the equivalent of the Dilworth sandstone of Gonzales County (see sections 1, 2, 3, 4, and 5, Pls. III and IV.)[67]

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[66]Ellisor, A. C., *op. cit.*, pp. 1311–1314

[67]Typical exposures of the Dilworth sandstone occur at the following localities: Singleton Grimes County; along Anderson Carlos road on the A. J. Sylvester 67-acre tract, Uriah Sanders Survey, 2.1 miles S. 37° E. of Carlos station, Grimes County; on the Fred Hill 10-acre tract and the Williams Estate 25-acre tract, J. B. Barrera Survey, 3.1 miles N. 60° W., 2.5 miles N. 55° W. of Millican, respectively, Brazos County; on the east bank of Brazos River, 500 feet south of the mouth of Boggy Creek, Walter Southerland Survey; on the Brenham-Caldwell State highway No. 36, on the south bank of Yegua Creek in the I. M. Hardeman Survey, Washington County; 3.1 miles N. 55° E. of Dilworth in a small draw which crosses the road in the southeastern part of the Wm. Buelow 200-acre tract, John A. Huesser Survey, Gonzales County; 1 mile south of Dilworth near the north corner of the A. W. Hill Survey, Gonzales County.

Miss Ellisor[65] places the Dilworth sandstone as the basal bed of her Whitsett formation, the latter being approximately equivalent to the Whitsett formation of this report. In Grimes, Brazos, and Washington counties where the Dilworth? sandstone forms an almost continuous outcrop, there are generally 50 to 70 feet of chocolate-colored sand and sandy clay above the Dilworth? sandstone identical in lithology with the beds below, and at the top of these chocolate-colored clay beds above the Dilworth sandstone there is generally a sharp change in lithology at the contact with the overlying tuffaceous cross-bedded sands of the Whitsett formation. (See Pl. I.) Therefore, the writer places the sandstone designated as Dilworth? within the Manning formation.

Lithologically the Dilworth? sandstone is very similar to the Carlos sandstone in that it has in many places impressions of pipes which resemble vegetable growth. It also contains impressions of stems and other vegetable matter and generally forms a massive ledge. At the top of this sandstone at many places are flaggy beds which carry fossil impressions. At some places the flaggy fossiliferous beds occur in the top layer of the massive phase of the Dilworth? sandstone and at other places in flaggy beds 4 to 6 feet above the massive sandstone and separated from the latter by lignitic sandy shale. These flaggy fossiliferous beds are included in the Dilworth? sandstone on the accompanying map, Plate VI. Two lists of invertebrates collected from these flaggy beds at the top of the Dilworth? are given on page 40. Below the Dilworth? sandstone there are generally several feet of soft sand interbedded with chocolate-colored clay and sandy clay. This sandstone is one of the most persistent markers in eastern Washington, Brazos, and Grimes counties and is very useful in mapping structures. It varies from 2 to 22 feet in thickness, the average being about 5 feet. (See sections 1, 2, 3, 4, and 5, Pls. III and IV, and sections H and I, Pl. V.)

Between central Washington County and Gonzales County no certain exposures of Dilworth sandstone were observed with the possible exception of the sandstone on the Claude Speed and E. Berry lands in Fayette County mentioned on page 38.

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[65]Ellisor, A. C., *op. cit.*, p. 1298.

The next observed appearance of the Dilworth sandstone to the southwest is in Gonzales County along the Gonzales-Moulton road in the southwest corner of the G. W. Cooper 163-acre tract, John A. Hueser Survey. Here it is poorly developed, consisting of thin flags of sand interbedded with clay, and the total thickness is only about 18 inches. Above are the cross-bedded tuffaceous sands of the Whitsett formation and below are chocolate-colored clays of the Manning formation. (See section G, Pl. V.) One and one-half miles southwest in a gully crossing the road near the southeast corner of the Wm. Buelow 200-acre tract, John A. Hueser Survey, the Dilworth sandstone is represented by an interval of about 4 feet consisting of sandstone flags one-half inch thick interbedded with chocolate-colored clay. Above the Dilworth sandstone are the typical gray to yellow cross-bedded tuffaceous sands of the Whitsett formation and below are also cross-bedded sands identical with those above. (See section 12, Pl. III, and sections B, C, F, G, H, and I, Pl. V.)

The absence of the Dilworth? sandstone over western Washington County and most of Fayette County may be explained in two ways: (1) There was a gradation from a beach environment where the sands of the Dilworth? sandstone were apparently deposited into fluviatile or palustrine environments, in both of which conditions most of the sediments of the Manning formation were also deposited; and (2) the fluviatile conditions which prevailed during the deposition of the succeeding Whitsett also obtained during the deposition of the Manning formation, thus removing some of the unconsolidated sand which gave rise to the Dilworth sandstone. It is likely that a combination of these conditions explains the absence of the Dilworth? sand over part of the area.

YUMA SANDSTONE

Along the Missouri Pacific Railroad track about 300 feet north of the station of Yuma and about 6000 feet west and 3300 feet south of the northeast corner of the Walter Southerland Survey, there are strata consisting mostly of flags of medium hard sandstone interbedded with soft sand and sandy shale (see Pl. X-B), and in the basal part of this section there is an earthy sandstone. The entire section at Yuma is about 25 feet thick and the name Yuma

sandstone[69] is here applied to this member, though it is recognized that it is possible that the strata here designated as Yuma may be the equivalent of the Dilworth sandstone of Gonzales County. (See p. 34.)

Northeastward across the John Millican and Wm. Devers surveys the Yuma sandstone forms a continuous outcrop, and in the southeastern part of the J. M. Barrera Survey it is involved in the minor but complicated faulting in that survey. In general in this faulted area it is identified by the presence of 10 feet or more of flaggy beds. It is not to be confused with the Dilworth? sandstone whose flaggy beds at the top do not generally exceed 4 feet in thickness.

Tracing the Yuma sandstone eastward from the Barrera Survey it was observed that the platy strata of the upper part of the section occupy less interval and the massive earthy sandstone in the lower part of the section becomes more conspicuous. This condition exists in the W. Brooks Association, A. G. Perry Survey, where the Yuma sandstone caps the top of the Navasota River bluff. (See Pl. VI.) In western Grimes County in the C. O. Edwards and B. B. B. & C. Railroad Company surveys where the Yuma sandstone forms a continuous exposed outcrop, the upper platy facies has disappeared, and the massive lower facies which is from 4 to 6 feet thick forms the entire outcrop, being sufficiently hard so that at several places it has been quarried for building stone.

Westward from central Brazos County the flaggy character seems to become less predominant, and in southeastern Burleson County the Yuma sandstone is more massive. Apparently the quarry on the Stone land about 4500 feet northeast and 800 feet northwest of the south corner of the J. Fisher Survey is in the Yuma sandstone.

Invertebrate casts were noted at a number of places in the Yuma sandstone but the number of forms is usually small. One collection from southern Brazos County is mentioned on page 40.

The Yuma sandstone is from 25 to 40 feet above the Dilworth sandstone. In western Grimes County there are about 20 feet of

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[69]Typical exposures of the Yuma sandstone are found at the following localities: along the abandoned Southern Pacific Railroad right-of-way, 1.4 miles N. 10° E. of Piedmont and about 700 feet north of the overhead bridge across the southeast corner of D. E. Allen 80-acre tract, Chas. O Edwards Survey, Grimes County, and northeastward and southwestward from this place; at the top of the bluff in the central part of the W. Brooks Association, A. G. Perry Survey, Brazos County; in the J. M. Barrera Survey, about 1500 feet east and 1200 feet north of the southwest corner, Brazos County; in the quarry on the Stone farm 4500 feet northeast and 500 feet northwest of the south corner of the J. Fisher Survey, 1 75 miles N. 56° E. of Clay station, Burleson County.

chocolate-colored lignite sands and clays separating the Yuma sandstone from typical strata of Whitsett lithology. Westward in eastern Brazos County this interval decreases, and in the J. M. Barrera Survey of south-central Brazos County and southwestward to Yuma where the flaggy sandstones at the top of the Yuma increase in thickness, the Whitsett strata are in contact with the Yuma sandstone; in fact, the soft sands interbedded with the flags resemble the Whitsett in lithology. In this part of Brazos County the top of the Yuma sandstone is mapped as the top of the Manning formation. (See Pls. III, IV, and VI.) It is probable that the interval occupied by chocolate-colored lignitic Manning beds above the Yuma in western Grimes County is not present in central and western Brazos County because the Yuma sandstone increases in thickness and occupies all of the interval represented by lignitic shale and sand to the east.

A sandstone which may be the Dilworth or more probably the Yuma sandstone was observed at one locality in Fayette County, this being about 2½ miles S. 30° E. of Muldoon along the road in the northwest part of the Claude Speed 113-acre tract and to the northeast in the central part of the E. Berry 112-acre tract, northwest part of Noah Karnes Survey. (See section A, Pl. V.) These outcrops are 1 mile southwest of section 9, Plate III, in which section the Dilworth and Yuma sandstones are absent. Above this sandstone on the Speed and Berry tracts are the typical gray cross-bedded tuffaceous sands of the Whitsett formation and below there are also gray cross-bedded sands of the Manning formation identical in lithology with the Whitsett formation above. The northernmost exposures of this sandstone are in the central part of the E. Berry 112-acre tract and although probably in the Manning formation at or near the top, the exact stratigraphic relations with respect to the top of the Manning formation are not apparent at this exposure. However, a quarter of a mile northeast of this locality, in a deep ravine near the southeast corner of the J. M. Ferrill Survey, the gray cross-bedded sands of the Whitsett formation may be observed resting on chocolate-colored clays of the Manning formation, and none of the massive sandstone is present. There are at least 25 feet of interbedded chocolate-colored clays and tan sands of the Manning formation exposed here, but below these chocolate-colored beds and within the Manning formation there are 50 feet or more

of gray cross-bedded sands similar in lithology to the sands of the Whitsett formation.

OTHER SANDSTONES IN THE MANNING FORMATION

In southern Burleson, northwestern Washington, and southeastern Lee counties (see sections 5, 6, 7, Pls. III and IV), there is a persistent sandstone ledge which varies from 3 to 6 feet in thickness and which is from 40 to 60 feet above the top of the Carlos sandstone. It varies from cross-bedded bentonitic to massive medium-grained quartz sandstone and is useful as a marker in that area.[70]

In Gonzales County there is a persistent gray sandstone bed from 90 to 100 feet above the Wellborn formation which is from 3 to 10 feet thick. (See sections F, G, and H, Pl. V.) At most places it stands out as a prominent ledge. (See Pl. VIII-B.)

STRATIGRAPHIC RELATIONS AND THICKNESS

Within the area shown on the accompanying map (Pl. II) the Manning formation is conformable on the underlying Wellborn formation. The thickness of the formation varies from 250 feet in eastern Grimes County to 350 feet in north-central Washington County and to about 250 feet in northern Gonzales County. In calculating surface thickness of this formation the regional dip was assumed to be the same as that of the Dilworth, Yuma, Carlos, and Bedias sandstones because these sandstones are the only beds on which it is practicable to run elevations for determining the dip.

PALEONTOLOGY AND AGE

Mollusks.—Collections were made from the flaggy fossiliferous sandstone zone at the top of the Dilworth? sandstone at several places in the J. M. Barrera Survey northwest of Millican and from the Yuma sandstone in Brazos County. These were sent to Miss Julia Gardner who kindly furnished the following data in a letter dated March 25, 1935.

1. Collection from the upper platy phase of the Dilworth? sandstone in a gully about 4400 feet west and 1000 feet north of the southeast corner of the J. M. Barrera Survey near the line between

[70]Exposures of this sandstone are found in the west corner of the J. Lastley Survey, Burleson County; north part of the L. Lowe 238-acre tract, B. M. Hatfield Survey, northwest Washington County; south corner of T. Freeman Survey, Lee County.

the Williams Estate 25-acre tract and the Henry Foster land about 2.15 miles N. 60° W. of Millican.

Mytilus sp. indet.
Arca? sp.
Spisula? sp.
Corbula? sp.

The *Spisula* is probably new and identical with an undescribed form that is abundant in the sandstones of Jackson age in Texas. Corbulas similar to that in your material are associated with similar Spisulas in a number of our collections from the Jackson of Texas so that although the name of the species is in doubt, the association and approximate position in the section seem fairly well established.

2. Collection from the platy, fossiliferous bed at the top of the Dilworth? sandstone in a ravine on the Fred Hill 40-acre tract about 1600 feet north and 2700 feet east of southwest corner of J. M. Barrera Survey, about 2.55 miles N. 67° W. of Millican.

Callocardia? sp.
Spisula? sp.
. . . similar to those in collections 1 and 3.

3. Collection from the Yuma sandstone about 2500 feet east and 200 feet south of northwest corner of Wm. Devers Survey, Brazos County, about 2.5 miles N. 72° W. of Millican.

Callocardia? sp.

A boring bivalve, genus and species unknown.

The *Callocardia* suggests the form which is called *Discoidalis* Conrad in the collections of the National Museum. The boring form is similar in size and shape to *Petricola* but without the hinge and external sculpture. Nothing can be done with it.

It is interesting that no trace of a gastropod has been observed in any of the three collections. Apparently your material is a remnant of an old sea beach frequented almost exclusively by bivalves which lived wholly or partially buried in the sand. The slab which carried the imprint of *Mytilus* suggests deposition on a tidal beach, for associated with the *Mytilus* are trails and possibly ripple marks; there are also numerous small pits which suggest raindrop impressions.

Plants and insects.—In the middle part of the Manning formation (see Pl. VI) at a locality where the I. & G. N.-Missouri Pacific Railroad crosses Boggy Creek on the J. C. Stuteville Survey, about

2.8 miles S. 8° E. of Wellborn, Brazos County, Berry[71] lists the following flora collected by Ball.

Antholithes balli Berry
Ardisia sp. Berry
Buettneria jacksoniana Berry
Bumelia balli Berry
Caenomyces jacksonensis Berry
Cedrela jacksoniana Berry
Chrysophyllum preoliviforme Berry
Citharexylon brazosense Berry
Combretum petraflumense Berry
Conocarpus eocenicus? Berry
Dodonaea viscosoides Berry
Ficus brazosensis Berry
Marchantites stephensoni Berry
Mespilodaphne texana Berry
Mimosites georgianus Berry
Myrcia ambiguaformis Berry
Nectandra antillanafolia Berry
Nipadites burtini umbonatus Bowerbank
Nyssa jacksoniana Berry
Papilionites erythrinaformis? Berry
Phoenicites sp. Berry
Rhamnites krugiodendroides Berry
Sapotacites millicanensis Berry
Tilia jacksoniana Berry

Ball[72] adds the following plants:

Bumelia wilcoxiana Berry
Eugenia yeguana Berry
Jungermanites bryopteroides Ball

Berry makes the following remarks in regard to this flora:

> This locality is remarkable for the diversity of its flora and for the abundance of the very variable leaves of *Combretum*, which must have been growing in the immediate vicinity in large numbers during this part of the Jackson. It contains a fine example of the rare *Marchanites stephensoni* and a characteristic new species of *Tilia*, the first representative of this genus that has been found in the Tertiary of the Atlantic Coastal Plain. Notable is the presence at this locality of the fruits of the Eocene littoral palm *Nipadites*, whose discovery here makes the range of this genus in the Mississippi embayment from Wilcox to Jackson, thus paralleling its range in the Old World.

In addition to the plants, Ball found the wings of the two following insects identified by Professor T. D. A. Cockerell:[73]

Eodichroma mirifica Cockerell (a dragon fly wing)
Formica eoptera Cockerell (an ant wing)

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[71]Berry, E. W., The Middle and Upper Eocene floras of southeastern North America U. S. Geol. Surv., Prof. Paper 92, p. 105, 1924.

[72]Ball, O M, A contribution to the paleobotany of the Eocene of Texas· Texas Agri. Mech. Coll., Bull, ser. 4, vol. 2, no. 5, p. 136 1931.

[73]Cockerell, T D A., Fossil insects from the Eocene of Texas. Amer. Jour. Sci., ser. 5, vol. 5, pp. 398–400, 1923.

Another locality from which Ball[74] collected plants that were identified by Berry[75] is along Alum Creek in the S. W. Robertson Survey, about 1 mile south of the east corner of the Robert Stevenson Survey.

The locality has not been visited by the author but it falls within the outcrop of the lower part of the Manning formation. (See Pl. VI.) The following list of species was given by Berry:

Apocynophyllum grevilleafolium Berry
Apocynophyllum texensis Berry
Bombacites jacksonensis Berry
Buriserites fayettensis Berry
Cedrela jacksoniana Berry
Conocarpus eocenicus Berry
Dodonaea viscosoides Berry
Dryophyllum brevipetiolatum Berry
Ficus claibornensis Berry
Inga jacksoniana Berry
Mespilodaphne caudata major Berry
Mespilodaphne texana Berry
Nectandra antillanafolia Berry
Pisonia balli Berry
Pisonia jacksoniana Berry
Sophora claiborniana Berry

The two species of *Apocynophyllum, Inga jacksoniana, Pisonia jacksoniana,* and *Sophora claiborniana* are the most abundant forms.

DEPOSITIONAL CONDITIONS

The lithology of the Manning formation indicates that these strata were deposited under palustrine, fluviatile, lagoonal, and littoral conditions. The large amount of lignitic material and silicified wood associated with many of the clays and sands shows that there was considerable vegetation at the time of deposition and the cross-bedded character of many of the beds is indicative of terrestrial conditions. The presence of lignite beds 1 to 3 feet in thickness shows that swamp environments prevailed at various times but the discontinuous nature of these lignitic beds indicates that swamp conditions did not obtain over the entire area at any one time. The Manning formation also contains beds which have been laid down by rivers or small streams and some of the strata suggest deltaic origin. Locally there are thin-bedded flat-lying shales with thin flags of sandstone which may represent lacustrine beds.

Many of the sands contain bentonitic material and in some places there are beds of bentonite up to 18 inches in thickness which suggest that they represent ash showers deposited in a body of

[74]Ball, O. M., *op. cit.*, p. 137.
[75]Berry, E. W., *op. cit.*, p. 104.

undisturbed water such as a lake or lagoon. It is difficult to account for the source of these ash deposits.

The Dilworth and Yuma sandstones probably represent deposits laid down close to strand line, possibly along a beach or in a very shallow water lagoon with a transgressive sea finally covering it and depositing marine sands at the top.

WHITSETT FORMATION

NAME AND LITERATURE

The history of Penrose's[76] name Fayette has been discussed in connection with the name Jackson on pages 13 to 17, and the subsequent restrictions of Fayette are shown diagrammatically in Plate I. Miss Ellisor[77] used the name Fayette for the topmost beds of the Jackson but subsequently she[78] applied the name Whitsett formation to the uppermost Jackson strata, Whitsett having previously been introduced by Dumble[79] in southwest Texas. In reviving the name Whitsett, Miss Ellisor states that:

> The United States Geological Survey, on the geological map of Texas issued in 1932, used the name Fayette to include all of the Jackson group. As Fayette has been printed on the map to include all the Jackson series, F. B. Plummer advised that a new name should be given to the upper, third formation.

The map referred to was the uncolored preliminary edition of the United States Geological Survey map of Texas, but it has since been decided to use Jackson group instead of Fayette. However, the name Whitsett formation has been adopted in this report to include the strata between the top of the Manning formation and the base of the Catahoula formation.

LITHOLOGY

The Whitsett formation is essentially a sand unit but there is considerable variation in the character of the materials included.

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[76]Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiary of Texas from Red River to the Rio Grande: Texas Geol Surv., 1st Ann. Rept., pp. 47–58, 1890.

[77]Ellisor, A. C., Jackson formation in Texas Presented at San Antonio meeting of the Society of Economic Paleontologists and Mineralogists, March, 1931. Unpublished.

[78]Ellisor, A. C., Jackson group of formations in Texas with notes on Fitio and Vicksburg: Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 1310–1317, 1933.

[79]Dumble, E. T., A revision of the Texas Tertiary section with special reference to the oil well geology of the coast region: Bull. Amer. Assoc. Petr Geol., vol. 8, pp. 433–434, 1924.

It consists of gray to cream-colored cross-bedded sands interbedded with some layers of thin-bedded bentonitic clay and some thin layers of chocolate-colored clay. The sands on weathering show thin seams of limonite-stained sand and locally they contain disseminated lignite.[80]

The sands and sandstones of the Whitsett formation are thinly laminated and highly cross-bedded. (See Pls. VIII-D and IX-A.) Ripple-marked surfaces were found at a number of places. They indicate shallow water conditions of deposition with rapidly changing direction of the currents. These depositional features distinguish the Whitsett formation from the Catahoula formation which in most places is massive and does not show bedding except locally. (See Pl. IX, C and D.) Another characteristic feature of the Whitsett formation, and one which helps to distinguish it from the Catahoula formation, is the presence of thin limonitic laminations parallel to

[80]Typical exposures of the Whitsett formation are present at the following localities: 1.7 miles S. 75° E. of Millican on K. T. Williams 110-acre tract and 1.5 miles N. 70° E. of Millican; in southeastern part of Milo Hens 762-acre tract, H. Evans Association, A. Millican Survey, Brazos County, at the west side of the Clay Creek dome on the J. Taylor 50-acre tract, J. F. Perry League, Washington County; 2.5 miles N. 8° W. of Cairnine along the road in the southwest corner of the Jas. Brown Survey, Washington County; 2.5 miles S. 60° E. of Muldoon along the road in the west part of the L. W. Kean Survey Fayette County; 2 miles N. 10° W. of La Grange in Colorado River bluff in the southeast part of the Fayette County School Land Subdivision, Fayette County; along the Gonzales-Moulton road, 5 miles S. 75° W. of Moulton in the south part of the G. W. Cooper 163-acre tract, John A. Huesel Survey.

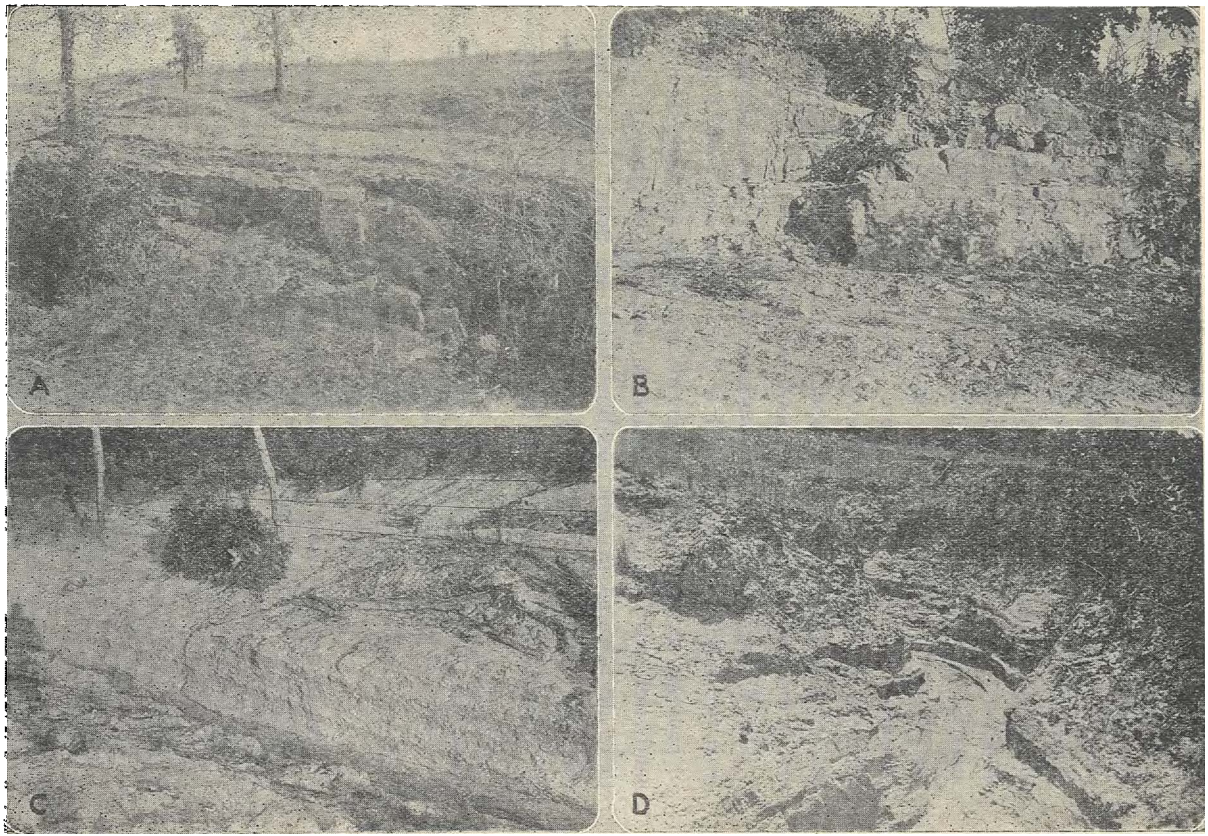
EXPLANATION OF PLATE VIII

A. Massive Dilworth sandstone on Fred Hill 40-acre tract, 1600 feet north and 2700 feet east of southwest corner of J. M. Barrera Survey, 2.5 miles N. 67° W. of Millican, Brazos County. (See section 3, Pls. III and IV.) The fossiliferous beds outcrop under the tree near the center of the photograph. (Looking east.)

B. Massive escarpment-forming sandstone in Manning formation along Moulton-Gonzales road, southeast part of W. B. Key 200-acre tract, Isaac D. Bradley Survey, Gonzales County, 3.1 miles N. 25° E. of Dilworth. (See section H, Pl. V; same locality as southwest corner of Sol. Parker 102-acre tract.)

C. Tuffaceous sand in lower part of Manning formation along Moulton-Gonzales road at northwest corner of Mrs. F. M. O. Roeker 257-acre tract, Isaac D. Bradley Survey. These strata are stratigraphically below those of Figure B. (See section H, Pl. V.)

D. Whitsett formation (gray cross-bedded tuffaceous sandstone) along road at southwest corner of V. Jurek 129-acre tract, Turner Barnes Survey, Gonzales County, 2.9 miles N. 78° W. of Moulton.


A
B
C
D

the bedding and limonitic concretions on the weathered surface while the Catahoula formation contains limonite stains only locally.

The most characteristic feature of the Whitsett formation is the abundance of tuffaceous material regardless of the environment in which the sediments were deposited. (See Pl. IX, A and C.) As previously pointed out, the Yegua formation contains some bentonitic sands and clays as do also the Caddell, Wellborn, and Manning formations, but this volcanic material became the predominant material in the Whitsett formation, and in central and southern Fayette and northern Gonzales counties tuffaceous strata are also present in the Manning formation. (See Pls. VIII-C and X-A.) In southern Brazos County there are several beds of sandy tuff in the Whitsett formation. The probable source of this volcanic material is discussed under the Catahoula formation.

The Whitsett formation in southern Brazos County contains at least two sandy tuff beds from 1 to 3 feet thick (see beds 4 and 6 of geologic section, p. 50) which are similar in all respects to the sandy tuff beds found in the Catahoula formation. In Brazos County there are two and in some localities three ash beds. One of these ash beds is very persistent and locally plant bearing and very useful in mapping structure.[51] (See bed 2, section on p. 50.) A typical

[51]In a letter dated November 27, 1931 C. S. Ross advises that the material from this bed consists of "glassy ash fragments, together with some detrital quartz. Very little alteration to bentonite." This rock is very light in weight

EXPLANATION OF PLATE IX

A. Whitsett formation along road near south corner of James Brown Survey, Washington County, 2 miles N. 7° W. of Carmine.

B. Oakville formation (Moulton sandstone member) along La Grange-Schulenburg road, State highway No. 44, exposed in the bluff south of Colorado River, Fayette County.

C. Whitsett formation below (thin-bedded gray or tan tuffaceous sand and clay) and Chita sandstone (massive tuffaceous) above, northwest side of Dilworth-Moulton road, 1.75 miles S. 70° E. of Dilworth on Wm. Green 1179.8-acre tract, George Blair Survey, Gonzales County.

D. Catahoula formation near the Plum-La Grange road in southwest part of the John Castleman Survey, 3.5 miles S. 65° W. of La Grange, Fayette County.

A
B
C
D

section of the lower part of the Catahoula formation and upper part of the Whitsett formation in Brazos County is shown in the following section.

Geologic section in southern Brazos County (lower Catahoula and upper Whitsett formations).[82]

	Thickness, Feet
Catahoula formation:	
Dunlap Quarry sandstone:	
17. Sandstone, massive to thin bedded; components of "rice grain" size to pebble size; exposed in southwestern part of K. T. Williams 290-acre tract and quarried in old Dunlap Quarry, 2 miles S. 15° E. of Millican	6
16. Green tuffaceous clay and sandy clay, lime nodules on weathered surface	21
15. Greenish-gray tuffaceous sandstone	3.5
14. Green tuffaceous sandy clay	25
Interval from top of Dunlap Quarry sandstone to top of Chita sandstone	55.5

[82]The Whitsett strata and Chita sandstone at the base of the Catahoula formation in this section were measured 1.5 miles N. 70° E. of Millican in a steep-walled ravine in the southeastern part of the Milo Heins 762-acre tract southwestward to the northwest part of the K. T. Williams 290-acre tract, H. Evans Association, A. Millican Survey. The Catahoula interval above the Chita sandstone was measured in a ravine at the northwest end of the old Dunlap Quarry about 2 miles S. 15° E. of Millican between the southwestern part of the Daisy Tatum 220-acre tract and the southeastern corner of the G. Dunlap 179-acre tract, E. M. Millican Survey.

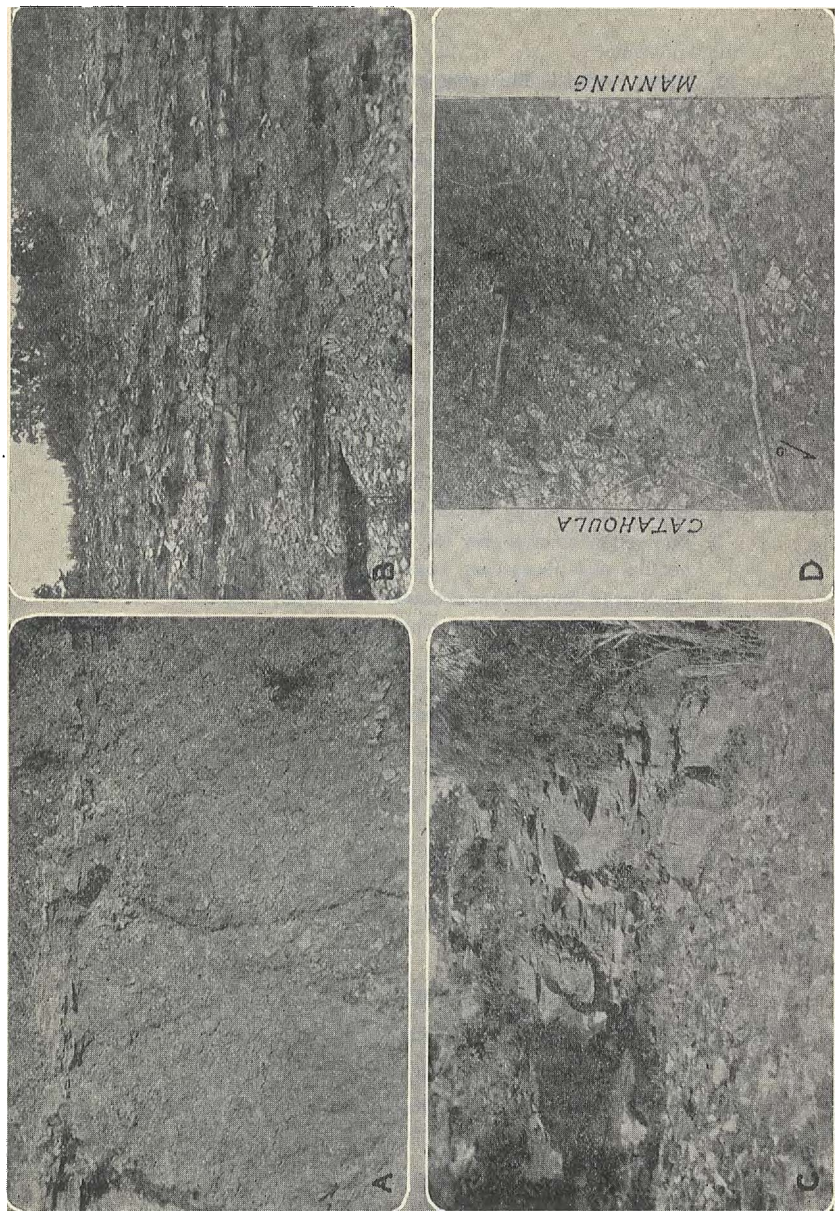
EXPLANATION OF PLATE X

A. Manning formation, tuffaceous leaf-bearing sand, resting on chocolate-colored clay in north-central part of San Antonio Ditch Company Survey, 2.8 miles S. 78° E. of Warda, Fayette County. (See section 8, Pl. III.)

B. Yuma sandstone of the Manning formation about 300 feet north of station of Yuma on Missouri Pacific Railroad, Walter Southerland Survey, Brazos County.

C. Dunlap Quarry sandstone of the Catahoula formation in the old Dunlap Quarry at a place 2.7 miles S. 20° E. of Millican, E. M. Millican Survey, Brazos County.

D. Millican fault 200 feet northeast of Humble Oil and Refining Company's pipe line, 2000 feet east and 2700 feet north of southwest corner of T. H. Mays Survey, Brazos County. (See Pl. VI.) Catahoula formation downthrown on the northwest side and Manning formation upthrown on the southeast side.


B
MANNING
CATAHOULA
D
A
C

	Thickness *Feet*
Chita sandstone:	
13. Massive cross-bedded conglomeratic sandstone grading into coarse tuffaceous sandstone	4
12. Soft gray ashy sandy clay	5
11. Massive conglomeratic sandstone	3
10. Soft gray tuffaceous sand and sandy clay	5
9. Massive cross-bedded conglomeratic sandstone grading into soft tuffaceous sand	4
(Chita sandstone well exposed in northwestern part of K. T. Williams 290-acre tract and across the fence in the Milo Heirs 762-acre tract.)	
Total Chita sandstone	21
Total lower part of Catahoula formation	76.5
Whitsett formation:	
8. Evenly bedded gray to chocolate-colored clay, limonite-stained and locally lignite-bearing	12
7. Buff-yellow to blue-gray soft tuffaceous sandy clay; limonite nodules and plates over weathered surface	11
6. Hard gray limonite-stained fractured sandy tuff	2.5
5. Gray clay with limonite plates and nodules on weathered surface	4
4. Hard gray limonite-stained fractured sandy tuff	2
3. Soft cross-bedded gray to buff sandstone; plates of limonite-stained sandstone	11
2. Soft battleship-gray ash; persistent in Brazos County	4.5
1. Gray to cream-colored soft argillaceous sand	6
Total exposed Whitsett formation	53

About 50 feet of Whitsett strata are present in this region below the base of the above section.

In western Grimes County the Whitsett formation consists largely of cross-bedded, poorly consolidated sand and contains more interlayered chocolate-colored clay than in Brazos County. No massive tuff beds like those in Brazos County were found in Grimes County. Southwestward in Washington, Fayette, and Gonzales counties the Whitsett consists largely of cross-bedded tuffaceous sand, clayey sand, and sandstone. (See sections 5 to 12, Pl. III and Pl. V.)

STRATIGRAPHIC RELATIONS AND THICKNESS

The base of the tuffaceous sands, tuff beds, and bentonitic beds typical of the Whitsett formation in Brazos and Grimes counties (see sections 2 to 5, Pls. III and IV) is 50 to 70 feet above the Dilworth? sandstone, but southwestward it is believed that due to interfingering and gradation into the upper part of the Manning formation these tuffaceous beds of Whitsett lithology gradually descend in the section, and in Gonzales County (see sections G, H, and I, Pl. V) the Whitsett formation rests directly on the Dilworth sandstone. Miss Ellisor[83] places the Dilworth sandstone as the basal bed of the Whitsett throughout the entire area.

In Fayette County gravel covers a large part of the county, and there is also a considerable amount of gray cross-bedded tuffaceous sand in the upper part of the Manning formation identical in lithology with the Whitsett formation, so that in many places in that county it is difficult to locate the base of the Whitsett formation exactly. (See sections 10 and 11, Pls. III and IV.)

In eastern Grimes County there is considerable gradation and interfingering of the Whitsett and Manning lithology, especially in the lower part of the Whitsett interval.

At some places in Grimes and Brazos counties the contact of the Whitsett formation with the underlying Manning formation is very sharp, but in other localities lenses of tuffaceous sands are present in the upper part of the Manning formation, and careful investigation is necessary in order to place the contact. At other places the cross-bedded grayish-green sands of the Whitsett formation, which are in part fluviatile, show channeling in the clays of the underlying formation. However, this channeling is not greater than that which is present at many levels within the Manning and Wellborn formations where fluviatile sands rest upon palustrine or lacustrine deposits.

The greater thickness of the Manning formation in sections 3, 4, and 5, Plates III and IV, is interpreted rather as the result of more rapid subsidence in a regionally low area than as an unconformity in the upper part of the Manning formation due to truncation to the northeast and southwest by the Whitsett formation. From the observations it is apparent that the Whitsett-Manning contact is

[83]Ellisor, A. C. *op. cit.*, pp. 1296 and 1314.

gradational at many places. No important unconformity is believed to exist at the base of the Whitsett formation or at any level within the Jackson group, though local disconformities such as stream channeling obtain throughout the group.

The thickness of the Whitsett formation varies from 75 to 132 feet and the dip ranges from 65 to 112 feet per mile in normal sections away from local structures. The amount of dip and thickness in general increases southwestward.

PALEONTOLOGY AND AGE

Fossil mollusks were not found in the Whitsett formation in Grimes, Brazos, and Washington counties, but about 4.5 miles N. 37° E. of Flatonia on the Joe Rosenauer 87-acre tract, B. Green Survey, Fayette County, Bowling and Wendler[84] collected fossils from tuffaceous sands in the Whitsett about 5 feet below the base of the Catahoula formation. They erroneously called these strata of the Jackson group lower Catahoula, and largely on the basis of this fauna, which was identified by Miss Julia Gardner of the United States Geological Survey as upper Jackson in age, they assigned an Eocene age to the lower part of the Catahoula formation. The stratigraphic position of the fauna from the Rosenauer tract is shown in section 10, Plates III and IV. Miss Gardner[85] advises that the upper Jackson fauna which she identified and listed at the bottom of page 534 and on page 535 in the Bowling and Wendler paper came entirely from the Rosenauer place.

Five and one-tenth miles S. 75° W. of Moulton on the Moulton-Gonzales road near the northwest corner of the J. Salzar 94-acre tract, J. A. Hueser Survey, the following fossils were found and identified by Miss Gardner.[86]

Leda sp. cf. L. mater Meyer
Venerid? sp. indet.
Mactrid? sp. indet.
Corbula sp. indet.
Indeterminate bivalves
Alectrion? sp. indet.
Latirus? or Phos? sp. indet.

Age determination: Upper Jackson

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[84]Bowling, Leslie and Wendler, A. P. Detailed study of some beds, commonly known as Catahoula formation, in Fayette County, Texas, with particular reference to their age: Bull. Amer. Assoc. Petr. Geol. vol. 17, pp. 534–535, 1933.

[85]Letter of January 8, 1934.

[86]Letter of October 7, 1933.

Miss Gardner advises that though this is not an imposing list of Jackson fossils, the *Leda* is a characteristic type, and the other forms, although not specifically determinable, are for the most part similar to forms found in Jackson outcrops.

On the J. Evans Survey No. 110 (see Pl. VI), about 2 miles north of Millican in Brazos County, Ball[87] collected the following flora which was identified by Berry. Ball reports much opalized wood and associated stumps in this flora. Fossil wood is very abundant in the Whitsett formation from which the plants were collected. (See Pl. VI.)

Anona ampla Berry
Apocynophyllum texensis Berry
Canna jacksoniana Berry
Sabalites vicksburgensis Berry

Almost a half mile west of the above locality, Ball[88] collected the following flora which was identified by Berry.[89]

Apocynophyllum grevilleafolium Berry
Apocynophyllum texensis Berry
Canna jacksoniana Berry
Cinnamomum spectabile? Heer
Combretum petraflumense Berry
Diospyros mirafloriana Berry
Fagara catahoulensis major Berry
Ficus mississippiensis (Lesquereux)
Inga jacksoniana Berry
Mespilodaphne caudata major Berry
Nectandra antillanafolia Berry
Sabalites vicksburgensis Berry

Berry made the following comments regarding the above flora:

> This is a typical mesophytic plant association and includes novelties in a beautiful new *Canna* and a form of *Ficus* not heretofore known at horizons younger than the Wilcox in the embayment region. It also includes abundant remains of a fan palm, some of the leaves of which are complete and stand upright in the clay. The most abundant form at this locality is the *Nectandra* in all sizes, and this, together with the palm and *Apocynophyllum grevilleafolium*, is the most abundant species.

Following oral directions given by Dr. Ball, the above-mentioned locality was visited and found to be in the eastern part of the J. M. Barrera Survey, about 5500 feet north and 1700 feet west of the southeast corner of that survey and about 800 feet south and 500 feet west of the northwest corner of the A. D. Lancaster Survey. The

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[87]Ball, O. M., *op. cit.*, p. 134.

[88]*Idem.*

[89]Berry, E. W., *op. cit.*, pp. 104–105.

fossil leaves occur in the ash bed about 40 feet below the top of the Whitsett formation which is approximately the same zone as bed 2 of the geologic section, page 50. Ross[90] states that the leaf-bearing material consists of volcanic glass and fine-grained, silty clay, glass shards being predominant, and some of the silt suggests reworking of the ash.

Berry[91] and Ball[92] refer to a locality from which fossil leaves were obtained from a draw in the Barrera Survey about 200 yards south of Peach Creek. The locality is about 6700 feet from the south line and 2400 feet from the westernmost east line of the survey, being about 700 feet southeast of the southeast corner of the J. M. McLaughlin Survey, Brazos County. The following plants were collected by Ball and identified by Berry:

Anacardites balli Berry
Ardisia sp. Berry
Buettneria jacksoniana Berry
Ceanothus jacksonensis Berry
Cedrela jacksoniana Berry
Coccolobis columbianus Berry
Combretum petraflumense Berry
Euonymus santatomasensis Berry
Ficus brazosensis Berry
Ficus sp. Berry
Mespilodaphne jacksonensis Berry
Mespilodaphne texana Berry
Myrcia catahoulensis Berry
Oreodaphne brazosensis Berry
Palmocarpon sessile Berry
Phoenicites sp. Berry
Pteris inquirenda Berry
Sapotacites millicanensis Berry
Smilax fayettensis Berry

To this list Ball added the following:

Phoenicites brazosensis Ball

This locality is within the outcrop of the lower part of the Whitsett formation. A sample of the rock was sent to C. S. Ross[93] who made the following statement:

> The dense specimen with conchoidal fracture shows no observable ash structure but is composed of very fine clay material and detrital quartz. The clay grains are so small that their character cannot be definitely determined, but it may be in part kaolinitic.

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[90]Ross, C. S., letter of February 8, 1935.
[91]Berry, E. W., *op. cit.*, p. 105
[92]Ball, O. M., *op. cit.*, p. 135.
[93]Letter of February 8, 1935.

Near Piedmont in Grimes County, Ball[94] obtained the following collection which was identified by Berry.[95]

Anacardites balli Berry	Dryophyllum brevipetiolatum Berry
Carpolithus balli Berry	Fagara catahoulensis var. Berry

DEPOSITIONAL CONDITIONS

The Whitsett formation is made up largely of fluviatile deposits. Stream channeling, cross-bedding, current and ripple marks are characteristic. The fluviatile sediments locally grade into beach sands and shallow water lagoonal deposits as shown by the fact that at a few places a marine fauna has been found in these beds. The evenly bedded nonmarine strata observed were probably deposited in lagoons or brackish water lakes at a number of places. Locally beds of probable deltaic origin were observed.

The disseminated lignitic fragments which occur at a few places in the Whitsett formation together with the abundance of silicified logs that are present throughout the area show that vegetable matter was transported and deposited. However, no beds of lignite were found in the Whitsett formation.

Ash showers must have been very common in Whitsett time because there is abundant tuffaceous material present in the formation regardless of the environment in which the sediments were deposited.

MIOCENE?

CATAHOULA FORMATION

NAME AND LITERATURE

Wailes[96] first designated the "Grand Gulf sandstone" which was exposed at Grand Gulf on Mississippi River in Claiborne County, Mississippi. Hilgard[97] used the term "Grand Gulf Group" in Mississippi. He stated that the "Grand Gulf Sandstone Proper" formed the bluff at Grand Gulf and was overlain by the Bluff formation.

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[94]Ball, O. M., *op. cit.*, p. 137.

[95]Berry, E. W., *op. cit.*, p. 105.

[96]Wailes, B. L. C., Report on the agriculture and geology of Mississippi, pp. 216–217, Jackson, Mississippi, 1854.

[97]Hilgard, E. W., Report on the geology and agriculture of the state of Mississippi, pp. 147–154, Jackson, Mississippi, 1860.

This description of the "Grand Gulf Sandstone Proper" is essentially equivalent to the Catahoula formation of today. Hilgard[98] later published a colored map showing the distribution of the "Grand Gulf Group" from Florida to the Rio Grande, this group embracing rocks from the present Yegua to Lagarto formations inclusive. He[99] published a number of other reports describing the Grand Gulf. Later Loughridge[100] included beds from Jackson to Lagarto in age in the Grand Gulf of Texas. Johnson[101] described the eastern continuation of these beds into Alabama and included within the Grand Gulf the present Hattiesburg and Pascagoula (approximately the Oakville and Lagarto equivalents in Texas). The "Lower Grand Gulf" of Smith[102] in Alabama contained certain beds lying above the Vicksburg limestone (then regarded as Eocene) and below the Chipola (Miocene). Miss Gardner[103] advised the writer that the Chipola cited by Smith at Roberts in Escambia County, Alabama, is now referred to the Oak Grove. Dall and Brown[104] used the term "Grand Gulf Series" to include beds from the Vicksburg (regarded as Eocene) to the top of the Alum Bluff beds and referred to a part of the lower "Grand Gulf Series" as the "typical Grand Gulf" (approximate Catahoula equivalent) and correlative with the lower Chattahoochee as known then. Dall[105] referred in 1892 the "Typical Grand Gulf" to the upper Oligocene. In Louisiana, Vaughan[106] then referred the

[98]Hilgard, E. W., The later Tertiary of the Gulf of Mexico: Amer. Jour. Sci., ser. 3 vol. 22, p. 58, 1881.

[99]Hilgard, E. W., Summary of results of a late geological reconnaissance of Louisiana: Amer. Jour. Sci., ser. 2, vol. 48, pp. 331–334, 1869.

———, ———, Preliminary report . . . of a geological reconnaissance of Louisiana: De Bow's New Orleans Monthly Review, vols. 37–38, pp. 754–769, 1869.

———, ———, On the geological history of the Gulf of Mexico: Amer. Jour. Sci., ser. 3 vol. 2, pp. 394–398, 1871.

———, ———, Supplementary and final report of a geological reconnaissance of Louisiana, 44 pp., New Orleans, 1873.

[100]Loughridge, R. H., Report on the cotton production of the state of Texas with a discussion of the general agricultural features of the state, *in* Physico-geographical and agricultural features of the state of Texas: U. S., Tenth Census, vol. 5, p. 21, 1884.

[101]Johnson, L. C., The Miocene group of Alabama: Science, vol. 21, pp. 90–91, 1893.

[102]Smith, E. A., Johnson, L. C., and Langdon, D. W., Report on the geology of the Coastal Plain of Alabama: Alabama Geol. Surv., p. 99, 1894.

[103]Gardner, Julia, personal communication.

[104]Dall, W. H. and Stanley-Brown, Joseph, Cenozoic geology along the Apalachicola River: Bull. Geol. Soc. Amer., vol. 5, pp. 117–170, 1894.

[105]Dall, W. H., Grand Gulf formation: Science, vol. 20, pp. 164–165, 319–320, 1892.

[106]Vaughan, T. W., A brief contribution to the geology and paleontology of northwestern Louisiana: U. S. Geol. Surv., Bull. 142, p. 24, 1896.

Vicksburg to the lower Oligocene and the Grand Gulf to the upper Oligocene, the age assignment of the latter being based entirely on field correlation as indicated by the following:

> The Upper Oligocene of Louisiana is represented by the Grand Gulf group of Hilgard. . . . So far no fossils, except a few plants, have been collected and determined from them, but they are referred to the Upper Oligocene because they are without doubt the same as the Grand Gulf of Mississippi, the age of which has been fixed.

Harris and Veatch[107] quote Dall and Brown for authority that the Grand Gulf passes below the Oak Grove sand in southern Alabama and argue that it is probably correlative with the Chattahoochee and of upper Oligocene age. Miss Maury[108] calls attention to the same stratigraphic relationship with respect to the Oak Grove sand.

In Alabama, Smith and Aldrich[109] included in the Grand Gulf beds resting on the Vicksburg as well as sands and clays resting "above any unquestioned Tertiary existing in Alabama."

The conflict between Dall[110] on the one hand and Smith and Aldrich[111] on the other lasted over a period of years.

Veatch,[112] though including some Jackson strata, used the name Grand Gulf in Texas. He assigned it to the Oligocene and stated that:

> . . . It would seem well to include under this term [Grand Gulf] the lower portion of Hilgard's Grand Gulf or that portion which contains sandstone beds. These form a stratigraphic unit readily distinguished from the thick beds of green calcareous clays which overlie them and which are now known to be Chattahoochee Oligocene.

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[107]Harris, G. C., and Veatch, A. C., A preliminary report on the geology of Louisiana: Louisiana State Exp. Sta., Geol. Agri. La., pt. 5, 354 pp., 1899.

[108]Maury, C. J., A comparison of the Oligocene of western Europe and the southern United States: Bull. Amer. Pal., no. 15, p. 70, 1902.

[109]Smith, E. A., and Aldrich, T. H., The Grand Gulf formation: Science, new ser., vol. 16, pp. 835–837, 1902.

[110]Dall, W. H., The Grand Gulf formation: Science, new ser., vol. 16, pp. 946–947, 1902.

———, ———, The Grand Gulf formation: Science, new ser., vol. 18, pp. 83–85, 1903.

[111]Smith, E. A., and Aldrich, T. H., The Grand Gulf formation: Science, new ser., vol. 18, pp. 20–26, 1903.

[112]Veatch, A. C., The geography and geology of the Sabine River: Louisiana State Exp. Sta., Geol. Agri. La., pt. 6, p. 132, 1902.

Because of the confusion caused by the use of the name Grand Gulf, Veatch[113] introduced the term Catahoula formation in Louisiana as a synonym for the "Typical Grand Gulf" of Hilgard. He assigned the Catahoula formation to the Oligocene and his lithologic description in Louisiana is essentially adequate for the Catahoula formation of Texas. However, the map in his later publication[114] showing the distribution of the Catahoula formation in Texas included beds of Jackson age. (See Pl. I.) Matson[115] later published a description of the Catahoula sandstone in Mississippi and Louisiana.

In Texas, Kennedy[116] applied Dumble's[117] name Frio to a number of typical Catahoula localities, as, for example, at Corrigan in Polk County and Riverside in Walker County. He also included the Fleming (Lagarto) in the Frio so that his Frio is about equivalent to Hilgard's "Grand Gulf Group." (See Pl. I.)

Dumble[118] states that Kennedy had applied the name Corrigan to approximately the same beds which Veatch later designated Catahoula. Evidently the name Corrigan was designated in some manuscript report as the writer was unable to find a description in the literature. Following is a quotation from Dumble's report regarding the Corrigan (see Pl. I):

> In the exposures of the Trinity River region, while the basal beds or Catahoula are the same as those to the eastward, there appears to be at the top a transitional zone, in which sands of the Corrigan type are interbedded with calcareous clays similar to those of the overlying Fleming. . . . For this [the upper] portion of the Corrigan the name Onalaska has been proposed. . . . Lithologically, the base corresponds closely with the typical Grand Gulf, while the top is very similar to some of the Oakville beds of the Nueces section, but older.

No calcareous clays have been found by this author in the Catahoula formation in the vicinity of Onalaska or higher in the

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[113]Veatch, A. C., The underground waters of northern Louisiana and southern Arkansas: Louisiana State Exp. Sta., Louisiana Geol. Surv., Bull. 1, pp. 84, 85, and 90, 1905.

———, ———, Geology and underground water resources of northern Louisiana with notes on adjoining districts: Louisiana Geol. Surv., Bull. 4, 209 pp., 1906.

[114]Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Surv., Prof. Paper 46, pp. 42–43, map, 1906.

[115]Matson, G. C., The Catahoula sandstone: U. S. Geol. Surv., Prof. Paper 98, pp. 209–226, 1916.

[116]Kennedy, W., The Eocene Tertiary of Texas east of the Brazos River: Acad. Nat. Sci. Philadelphia, Proc. 1895, pp. 93–95, 1896.

[117]Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geol., vol. 2, pp. 549–567, 1894.

[118]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, pp. 188–189, 1918.

Catahoula section southeast of the village. Some of the clays near Onalaska are gray in color and resemble the gray calcareous clays of the Oakville and Lagarto formations, but no reaction was obtained with hydrochloric acid. Dumble[119] considered that his Corrigan probably contained two formations, as shown by the following statement:

> It seems probable that the Corrigan represents some portion or all of the Oligocene above the Vicksburg, and that while the base may be Grand Gulf, the upper portion is possibly Miocene.

Deussen[120] stated that the strata shown as Catahoula on his geological map of 1914 were not a single stratigraphic unit but consisted of rocks of Jackson (Eocene) and Oligocene ages. Within the Catahoula symbol on his map are included beds from the base of the Caddell formation, in some places, and the base of the Wellborn formation in other places, to the top of the Catahoula formation.

However, Deussen's[121] reconnaissance map of 1924 showed the Catahoula formation from Brazos River to southern Fayette County approximately as it is on the accompanying map, Plate II. From southern Fayette County and continuing southwestward he assigned to the Frio strata which are continuous with the Catahoula formation as shown on Plate II of this paper. (See Pl. I.)

Strata of typical Catahoula lithology and continuous with the Catahoula outcrop of east Texas were designated as Gueydan by Bailey[122] who gave an excellent petrologic description of these rocks. It is unfortunate that the name Gueydan was introduced but it has since been dropped in favor of Catahoula by the United States Geological Survey. Gueydan group has recently been revived by Plummer[123] to include the Catahoula and Frio formations.

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[119]Dumble, E. T., *op. cit.*, p. 189.

[120]Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Surv., Water-Supply Paper 335, footnote 1, p. 70, map, 1914.

[121]Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, map, 1924.

[122]Bailey, T. L., Extensive volcanic activity in the Middle Tertiary of the south Texas Coastal Plain: Science, new ser. vol. 59, pp. 299–300 1924.

———, ——— The Gueydan, a new Middle Tertiary formation from the southwestern Coastal Plain of Texas: Univ. Texas Bull. 2645, pp 42–52 1926 [1927].

[123]Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas, Vol. I, Stratigraphy: Univ Texas Bull. 3232, p. 70. 1932 [1933].

The Frio formation which appears in Live Oak County occupying a position between the Catahoula formation and the Jackson group is not recognized on the surface in the area covered by the accompanying map (Pl. II).

LITHOLOGY

The lithology of the Catahoula formation has been described by Veatch[124] and Matson[125] in Louisiana. Shearer[126] has more recently given a good description of the Catahoula formation as exposed in Catahoula and La Salle parishes, Louisiana. The Catahoula formation in Texas consis.s largely of tuffaceous clays and sandy clays but interbedded with the latter are tuffaceous sands and tuff beds. There are also several conglomeratic sandstone and quartzite beds which are described subsequently. These hard sandstone and quartzite beds together with some of the more resistant tuff beds are resistant to erosion and give rise to ridges or cuestas with a resulting dissected topography at many places.

On fresh exposures the clays are characterized by their green color and conchoidal fracture. On weathering, these clays often assume a whitish color, and on the weathered outcrop there are commonly small pellets and nodules of calcium carbonate.

Bailey[127] gave an excellent description of the lithology of the Gueydan (Catahoula) in southwest Texas. In that area he divided this formation into the Fant, Soledad, and Chusa members named in ascending order. The Fant and Chusa consist largely of sandy tuffs and tuffaceous clays while the Soledad consists largely of sandstone and conglomerate, the boulders of which attain a maximum diameter of 2 feet. The Soledad has no representation in the area northeast of Guadalupe River, and it is probable that the Chusa is not present. The lithology of the Catahoula formation northeast of Guadalupe River is similar to the Fant but it does not contain any volcanic conglomerate.

Eight samples of Fant tuff examined petrologically by Bailey showed the following constituents: volcanic glass, 10 to 70 per cent;

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[124]Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Surv., Prof. Paper 46, p. 43, 1906.

[125]Matson, G. C., *op. cit.*, pp. 213–215.

[126]Shearer, H. K., Geology of Catahoula Parish, Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 14, pp. 433–450, 1930.

[127]Bailey, T. L., The Gueydan, a new Middle Tertiary formation from the southwestern Coastal Plain of Texas: Univ. Texas Bull. 2645, pp. 129–134, 1926 [1927].

albite to oligoclase feldspar, 3 to 25 per cent; sanidine, 1 to 12 per cent; opal, 1 to 72 per cent, common replacement after glass; tridymite, 0 to 12 per cent; "leverrierite," 0 to 10 per cent; and traces of chalcedony, chert, quartz, pyrite, marcasite, magnetite, ilmenite, orthoclase, zircon, apatite, chlorite, augite, serpentine, chabazite or gemlinite, with traces of barite and witherite as vein filling and fragments of andesite or trachyandesite. Facilities were not available for petrographic examination of the tuffs in the area considered in this paper, but they are probably similar in composition to those of southwest Texas where, as noted above, they are of intermediate composition.

The green clays are entirely noncalcareous in Grimes and Brazos counties so that the calcareous pellets and nodules found on the weathered outcrop are undoubtedly of secondary origin and were presumably concentrated by ground water. Mapping southwestward, the first calcareous beds observed occur as a thin concretionary bed about the middle of the formation on the southeast side of the Clay Creek dome in Washington County along the southwest line of Mrs. M. Klatte 60-acre tract, N. Clay Survey. With the exception of this concretionary bed, the Catahoula formation from Washington County northeastward contains no calcareous material and the reaction with dilute hydrochloric acid may be used to separate the Catahoula formation from the calcareous Oakville formation above.

In tracing the Catahoula formation from Grimes County southwestward, the first observed calcareous sandstone was found 2.9 miles S. 35° E. of Muldoon, Fayette County, at the junction of the Flatonia-La Grange road and the Muldoon-La Grange road in the southwest part of the Paul Olle land along the south line of the E. W. Kean Survey. This calcareous sandstone is about 65 feet above the base of the formation and its position is shown in section 9, Plate III. It is cross-bedded and medium grained and in many respects resembles some of the sandstones in the Oakville formation. Eastward along this road there are calcareous sandy clay beds above the sandstone and about 110 feet above the base of the formation.

Southwestward from this locality the Catahoula formation contains calcareous sandstone and grits lower in the section, and from the north part of the H. J. Grieve 30-acre tract, John Morris Survey,

east corner of Gonzales County, southward calcareous sandstone occurs at the base of the formation.

North of Moulton in Lavaca County the Catahoula formation is made up largely of green clays with several thin beds of calcareous sandstone. However, southwest of the town of Moulton in the central part of the Wm. Chase Survey calcareous sandstones are present in the Catahoula formation in profusion, and southward from this point the Catahoula formation contains a large amount of calcareous sandstones. Due to the presence of this calcareous sandstone the Catahoula resembles the overlapping Oakville formation, but this calcareous sandstone within the Catahoula formation is a feature of lateral gradation and does not represent the complete surface overlap of the Oakville formation onto the basal Catahoula or Whitsett formations.

In the lower part of the Catahoula there are two persistent and mappable sandstone beds which are called the Chita sandstone and the Dunlap Quarry sandstone.

CHITA SANDSTONE MEMBER

Plummer[128] applied the name Chita to the basal sandstone of the Catahoula formation, but he included more strata than are represented by the basal Catahoula sands in this area. The town of Chita is located 9.2 miles N. 85° E. of Trinity in Trinity County. The maximum thickness observed in the area shown on Plate III is 20 feet, but Plummer records a maximum of 80 feet, so that in Trinity and Polk counties he may have included all the strata from the base of the Catahoula formation to the Dunlap Quarry sandstone. In this paper the name Chita is applied only to the basal bed of the Catahoula formation which nowhere exceeded 25 feet in thickness.

There are several different facies of this sandstone, the most conspicuous facies being that which consists of coarse quartz sand grains and grit with siliceous cement.[129] Locally the rock is metamorphosed

[128]Plummer, F. B., *op cit.*, pp. 715–716.

[129]Typical exposures of the quartzitic phase of the Chita sandstone at the base of the Catahoula occur at the following localities: along the north line of the Lula Dodd 200-acre tract, Cyrus Campbell Survey, 2.7 miles N. 70° E. of Singleton, Grimes County; along the Southern Pacific Railroad (Navasota to Mexia branch, now abandoned) in the east-central part of the R. L. Jones et al. 613 acre tract, W. R. Saunders Survey, 2.3 miles S. 28° W. of Piedmont, Grimes County; along the west part of the north line of K. T. Williams 290-acre tract H. Evans Association, A. Millican Survey, 1.5 miles N. 70° E. of Millican, Brazos

to a quartzite. At many places the quartz grains in this grit are about the size of rice grains which led Dumble[130] to refer to them as the rice sands and sandstones. In places this Chita sandstone is conglomeratic, containing pebbles of quartz, jasper, opal, chert, and other siliceous fragments. The maximum diameter of the pebbles in the conglomerate is usually about one-half inch, most of which are well rounded. The Chita quartzitic facies grades into sandy tuff, and at many places a conspicuous bed of sandy tuff 3 to 6 feet in thickness marks the base of the Catahoula formation.[131] Locally the conglomeratic sandstone near the base of the Chita sandstone contains beds with an abundance of rounded clay pellets up to an inch or more in diameter in a matrix of sandy tuff.

In Grimes, Brazos, Washington, and Fayette counties no calcareous beds were observed in the Chita sandstone, but in the northeast corner of Gonzales County along the secondary road near the northeast corner of the T. T. Woods 171-acre tract, John Morris Survey, the base of the Catahoula formation is marked by a conglomerate containing limestone pebbles up to one-half inch in diameter together with smaller quartz pebbles all in a carbonate matrix.

Likewise in northwestern Lavaca County at the southwest corner of the Philander Priestly Survey, 2½ miles N. 70° W. of Moulton, and about 15 feet above the base of the formation, there are coarse gritty cross-bedded sands and sandstones with calcareous matrix containing silicified logs. Similar calcareous sandstones and grit were observed in the basal beds of the Catahoula along the creek which crosses the east part of Mrs. J. M. Bell 186-acre tract, Wm. R. Strapp Survey, 3¾ miles N. 68° E. of Dilworth, Gonzales County.

County; 0.1 mile northeast of the east corner of E. Darcus 80-acre tract, L. Lessassier Survey, 2.3 miles N 70° W. of Independence, Washington County; along the Somerville-Brenham State highway No. 36, about 0.5 mile southeast of quarry at the south corner of the N. Whitehead Survey, Washington County; along the southeast line of the J. P. Longley Survey, 3¾ miles S. 75° E. of Waida, Fayette County; at the southwest corner of the Philander Priestly Survey, 2.5 miles N. 75° W. of Moulton, Lavaca County; in the cuesta in the northeast part of E. Medley 435-acre tract, James H. Isbell Survey, 3 miles N. 63° E. of Dilworth, Gonzales County.

[130]Dumble, E. T., The geology of east Texas: Univ. Texas Bull 1869, p. 188, 1918.

[131]The tuffaceous phase of the Chita sandstone is fairly persistent across southern Fayette County and is present at the following localities: southeast part of Joe Rosenauer 87-acre tract, Benjamin Green Survey, 4.5 miles N. 38° E. of Flatonia, and southwestward near the southwest corner of the W. C. Koch 258-acre tract, M Muldoon Survey, 2 miles N. 43° E. of Flatonia, Fayette County; on the Wm. Bailey Estate 403-acre tract, George E. Blair Survey, 2.2 miles N. 81° E. of Dilworth, Gonzales County.

DUNLAP QUARRY SANDSTONE MEMBER

From eastern Grimes County to northern Fayette County there is present in the lower part of the Catahoula formation a massive, conglomeratic, noncalcareous sandstone which is here designated the Dunlap Quarry sandstone. It is well exposed in the large quarry located on the G. W. Dunlap 167-acre tract in the southeast part of the E. M. Millican Survey, 2.4 miles S. 17° E. of Millican, Brazos County.[132] (See Pl. X-C.) However, southward from northern Fayette County the writer was unable to find this bed. (See sections 1 to 7, Pls. III and IV.) This sandstone consists of coarse rice sand, tuffaceous sand, grit, and conglomerate and locally grades into tuff. In fact the description of the Chita sandstone is applicable also to the Dunlap Quarry sandstone. Where it is present, the thickness varies from 4 to 25 feet.

OTHER SANDSTONES

There are other sandstones present in the section in addition to those mentioned above. Most of these are of little importance.

In addition to the Chita sandstone and the Dunlap Quarry sandstone there is in eastern Grimes County another persistent sandstone as shown in section 1, Plate III, which occurs about 35 feet below the base of the Oakville formation but which to the southwest is apparently overlapped by the basal Oakville. This sandstone grades from a medium-grained sandstone into grit and is locally quartzitic.[133]

STRATIGRAPHIC RELATIONS AND THICKNESS

The stratigraphic relations at the base of the Catahoula formation as described in Texas, Louisiana, Mississippi, and Alabama are contradictory as shown by the following:

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[132]Representative exposures of the Dunlap Quarry sandstone are found at the following localities: along the road on the south line of the Mrs. M. V. Williamson 130-acre tract, John G. Conner Survey, 3 miles N. 18° E. of Red Top, Grimes County; along the T. & B. V. Railroad, 1.4 miles N. 50° W. of Shiro, Grimes County; along the Navasota-Piedmont road in the southeast part of the J. D. Moody 616-acre tract, Hanna Cornaugh Survey, Grimes County; at the old quarry site on the G. W. Dunlap 167-acre tract, E. M. Millican Survey, 2.4 miles S. 17° E. of Millican, Brazos County; in the southeast part of Mrs. H. N. Anderson 390-acre tract, L. Lessassier Survey, 2 miles N. 70° W. of Independence, Washington County; along the Brenham-Somerville State highway No. 36, 0.2 mile northwest of the southeast corner of C. H. Steinkamp 70-acre tract, H. Chriesman Survey, 1 mile N. 5° E. of Gay Hill station, Washington County.

[133]Typical exposures of this sandstone occur along the Anderson-Carlos road, 1.9 miles N. 15° W. of Anderson along the west line of the Johanna Steinhagen land, northwest part of M. D. Black Survey, and 1 mile S. 15° E. of Roan's Prairie at the northwest corner of the Mrs. Chas Brigance 100-acre tract, Joshua Hadey Survey, Grimes County.

In Mississippi, Hilgard[134] concluded that the basal Grand Gulf rested unconformably on the Vicksburg, and Veatch[135] and Harris[136] pointed out that the Grand Gulf beds in western Louisiana overlapped the Vicksburg and rested on the Jackson. Matson[137] stated that in southern Mississippi and Alabama the Catahoula rested conformably on the Vicksburg. Dumble[138] apparently regarded his Corrigan as unconformable on the Jackson. Deussen[139] stated that the Catahoula "lies conformably above the Fayette sandstone in Washington and Fayette counties. . . ."

In the area shown on the accompanying map (Pl. II) the Catahoula formation at the surface rests unconformably on the underlying Whitsett formation, as shown by the Jackson group having a greater dip than the overlying Catahoula formation. The most striking evidence of this unconformity is found at the Clay Creek dome,[140] Washington County, which was discovered for the Sun Oil Company by W. B. Ferguson. Here all of the wells have been carefully cored. Ferguson[141] and Waters[142] advise that the Catahoula rests across the truncated edges of all formations from the Whitsett formation down to the Caddell formation, and Ferguson states that the contact of the Catahoula and Caddell formations is found in the Sun Oil Company No. 7 Grote. (See section 4, Pls. III and IV.)

Miss Ellisor[143] has recently called attention to this unconformity, and her columnar sections show that the Catahoula formation in

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[134]Hilgard, E. W., The later Tertiary of the Gulf of Mexico: Amer. Jour. Sci., ser. 3, vol. 22, pp. 58–65, 1881.

[135]Veatch, A. C., The geography and geology of the Sabine River: Louisiana State Exp. Sta., Geol. Agri. La., pt. 6, p. 132, 1902.

[136]Harris, G. D., The geology of the Mississippi embayment with special reference to the state of Louisiana: Louisiana State Exp. Sta., Geol. Agri. La., pt. 6, p. 28, 1902.

[137]Matson, G. C., The Catahoula sandstone: U. S. Geol. Surv., Prof. Paper 98, pp. 225–226, 1916.

[138]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, pp. 186–187, 1918.

[139]Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, p. 100, 1924.

[140]Heath, F. E., Waters, J. A., and Ferguson, W. B., Clay Creek salt dome, Washington County, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 15, pp. 43–60, 1931; discussion by F. H. Lahee, pp. 279–283 and pp. 1113–1116; discussion by M. I. Goldman, pp. 1105–1113.

[141]Ferguson, W. B., personal communication, July 25, 1933. See also: Ferguson, W. B., and Minton, J. W., Clay Creek salt dome, Washington County, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 20, fig. 9, p. 88, wells 5 and 10, 1936.

[142]Waters, J. A., personal communication, August 4, 1933.

[143]Ellisor, A. C., Jackson group of formations in Texas with notes on Frio and Vicksburg: Bull. Amer. Assoc. Petr. Geol., vol. 17, fig. 7, p. 1330, 1933.

Live Oak County rests on higher Jackson beds than in the country to the northeast.

Miss Ellisor[141] states that:

> In the wells a large unconformity exists at the top of the Whitsett east of the Atascosa and Karnes county line. On the surface in addition to this unconformity the beds are progressively overlapped by the Catahoula so that in Fayette County south of Muldoon and east for a distance the Whitsett formation is completely covered by the Catahoula. As the geology has not been mapped in detail between Fayette and Trinity counties, it is impossible to state exactly how much of the Whitsett is exposed.

In support of this statement, Miss Ellisor's "Section south of Muldoon," in her figure 7, shows the Catahoula formation resting on the Dilworth sand with the Whitsett formation removed by erosion, but her section does not correctly depict the geologic section exposed at the surface. The Catahoula formation here rests directly on the Whitsett formation, and at no place on the surface within the area shown on Plate II was the Catahoula found to truncate beds below the Whitsett formation. The relations southeast of Muldoon may have been confused by the fact that the Yuma? sandstone grades out laterally or has been removed by some channeling at the base of the Whitsett formation as explained on page 38.

The stratigraphic relations at the base of the Catahoula formation shown in the section of Miss Ellisor's are presumed to exist in the west part of the E. Berry 112-acre tract, Noah Karnes Survey, but east along the road on the south side of this tract and above the Yuma? sandstone are typical Whitsett beds. (See p. 38 and section A, Pl. V.) Also in the deep branch in the northwest part of the Mrs. R. F. Speed 47-acre tract, at the north part of the Noah Karnes Survey, and near the southeast corner of the M. Ferrill Survey, typical Whitsett strata rest on chocolate-colored clays of the Manning member with the suggestion of channeling at the top of the latter. Section 9, Plate III, is located one-half mile northeast of the last-mentioned locality.

The outcropping Catahoula formation as measured on the surface in this area is thickest in Washington, Burleson, and Brazos counties. There the thickness varies between 225 and 310 feet and is

[141] *Idem.*, p. 1311.

about 250 feet in average. Southwestward this formation is gradually overlapped, and from northern Fayette County southwest the width of outcrop decreases and only the lower part of the Catahoula formation is exposed. The thinnest measured sections are in eastern Gonzales County where only 55 feet of the lower part of the formation outcrops. (See sections F, G, H, and I, Pl. V.) The thicknesses of the Catahoula formation were measured by determining the dip of the Chita sandstone and Dunlap Quarry sandstone at a number of places. This dip was found to vary from 60 to 105 feet per mile (see section 5, Pl. III), the maximum observed dip of 105 feet per mile occurring on the Brenham-Caldwell State highway No. 36 west of Clay Creek dome where abnormal structural conditions obtain. The average dip is between 70 and 75 feet per mile.

That the dips and thicknesses of the Catahoula intervals as determined on the surface are approximately correct is confirmed by some data kindly furnished the writer by W. B. Ferguson, where in the vicinity of Burton, Washington County, the Sun Oil Company drilled several core tests and found the thickness to vary from 222 to 312 feet.[145]

PALEONTOLOGY AND AGE

The Grand Gulf group was regarded as Miocene by McGee[146] and other geologists, and Dall and Harris[147] stated that the upper part of the Grand Gulf was not older than the latest Miocene. Dall[148] assigned lower Grand Gulf or "typical Grand Gulf" to the upper

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[145]Thicknesses of the Catahoula formation as obtained by the Sun Oil Company in several core tests in the vicinity of Burton are: Sun Maas D-1, thickness 222 feet, located 1.5 miles N. 37° E. of Burton near the south corner of the R. O. Maas 116 acre tract, I. McCain Survey; Sun Quade D-1, thickness 234 feet, located 3.1 miles N. 87° E. of Burton in the northwest part of the Emil Quade 143-acre tract, J. M. Button Survey; Sun Beckerman D-1, thickness 312 feet, located 4.8 miles S. 57° E. of Burton in the central part of Ben Beckerman 131-acre tract, W. Pryor Survey.

The Sun Maas D-1 is located about 0.5 mile southeast of the Oakville-Catahoula contact the Sun Quade D-1 about 3 miles southeast of the contact, and the Sun Beckerman D-1 about 6.7 miles southeast of the contact.

[146]McGee, W. J., The southern extension of the Appomattox formation: Amer. Jour. Sci., ser. 3, vol. 10, p. 32, 1890

[147]Dall, W. H., and Harris, G. D., Correlation papers: Neocene: U. S. Geol. Surv. Bull 84, p. 165, 1892.

[148]Dall, W. H., A table of the North American Tertiary formations, correlated with one another and with those of western Europe, with annotations: U. S. Geol. Surv., 18th Ann. Rept., pt. 2, table facing p. 334, 1898.

Dall, W. H., and Stanley-Brown, Joseph, Cenozoic geology along the Apalachicola River: Bull. Geol. Soc. Amer., vol. 5, pp. 147–170, 1894.

Oligocene and correlative with the lower Chattahoochee, and Vaughan[149] also referred it to the upper Oligocene. Veatch[150] pointed out that in Alabama it graded into fossiliferous clays and sands of the Chattahoochee. Matson[151] stated that "In eastern Louisiana, the Catahoula sandstone dovetails with the Vicksburg . . ." He was in accord with Veatch when he stated that "The marine Chattahoochee formation passes westward in Alabama by gradation through fossiliferous marls into the nonmarine sandstones and clays of the Catahoula." On the basis of this eastward gradation into the marine Chattahoochee, which was at that time referred to the Oligocene, Veatch and Matson assigned the Catahoula to the Oligocene. However, Cooke and Mossom[152] point out that the Chattahoochee is Miocene and of the same age as the Tampa limestone, which, they say:

> . . . is generally regarded as the time equivalent of the Catahoula sandstone of the Gulf States, but as this correlation is based chiefly upon the relative stratigraphic positions of the two formations and is not supported by reliable paleontologic evidence, it should be regarded as merely provisional.

Cooke[153] further states:

> I have little definite information about the exact age of the Catahoula sandstone except that the typical Catahoula of Catahoula Parish, Louisiana, overlies the upper Oligocene Byram marl and therefore is probably lower Miocene. It is probably equivalent to the Tampa limestone.

The Tampa, like the Chattahoochee, was formerly referred to the Oligocene,[154] but the arbitrary boundary between the Miocene and the Oligocene has since been shifted downward to the base of what was once called upper Oligocene.

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[149]Vaughan, T. W., A brief contribution to the geology and paleontology of northwestern Louisiana: U. S. Geol. Surv., Bull. 142, p. 26, 1896.

[150]Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Surv., Prof. Paper 46, p. 43, 1906.

[151]Matson, G. C., *op. cit.*, pp. 224–226.

[152]Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida State Geol. Surv., 20th Ann. Rept., p. 83, 1928.

[153]Cooke, C. W., personal communication, January 9, 1934.

[154]Dall, W. H., A monograph of the molluscan fauna of the *Orthaulax pugnax* zone of the Oligocene of Tampa, Florida: U. S. Nat. Mus., Bull. 90, 173 pp., 1915.

Berry[155] in a companion paper to the one by Matson on the Catahoula said ". . . the facies of the flora as a whole is that of the abundant floras found in the early Oligocene of southern Europe. . . ."

Dumble[156] considered the Corrigan sandstone for the most part upper Oligocene in age. Tatum[157] says that the southern continuation of the Gueydan (Catahoula) into Mexico contains marine beds in the vicinity of Tampico which have been identified as basal Oligocene.[158] Deussen[159] refers the Catahoula formation to the Oligocene but in discussing the Oakville formation refers to the jawbone of an extinct rhinoceros collected on the Derrick farm in Washington County. (See his Pl. XXVIII.)

This bone was examined by J. W. Gidley of the United States National Museum who advised Deussen as follows:

> The bone from Washington County, Texas (see Pl. XXVIII), is a part of an upper jaw containing four anterior teeth on the left side. It represents an extinct species of rhinoceros. The teeth are so much worn, however, that the specimen cannot be assigned to any particular species, but it is apparently new. It resembles in some respects some of the European late Miocene Aceratheres, and it may be provisionally assigned to the genus *Coenopus*. The development of the premolars, as indicated by the great prominence of their posterior internal cusps, is further advanced than in any known Oligocene form, so that the species may probably be referable to a middle or upper Miocene horizon, perhaps even to one in the Pliocene.

The locality from which this bone was reported to have been found is about 4.5 miles west of Burton on the J. P. Derrick 17-acre tract in the west-central part of the O. Hudson Survey, Washington County, and was visited by this author in company with Mr. F. Derrick, the original discoverer of the bone. Though no additional

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[155]Berry, E. W., The flora of the Catahoula sandstone: U. S. Geol. Surv., Prof. Paper 98, p. 229, 1916.

[156]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, p. 188, 1918.

[157]Tatum, J. T., General geology of northeast Mexico: Bull Amer. Assoc. Petr. Geol., vol. 15, pp. 881–882, 1931.

[158]Dickerson, R. E., and Kew, W. S. W., The fauna of a medial Tertiary formation and the associated horizons of northeastern Mexico: Proc. California Acad. Sci., ser. 4, vol. 7, pp. 125–156, 1917.

Böse, Emil, and Cavins, O. A., The Cretaceous and Tertiary of southern Texas and northern Mexico: Univ. Texas Bull. 2748, pp. 7–142, 1927 [1928].

[159]Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, p. 103, Pl. XXVIII, 1924.

bones were found it was observed that the outcrop was not in the Oakville but well within the Catahoula; the position of this locality is shown in section 6, Plate III. On the basis of the determination of this bone by Gidley, it appears that part of the Catahoula at least is Miocene. The fact that this bone locality on the Derrick farm is within the Catahoula formation has previously been pointed out by Weeks.[160] Just as this paper was ready for printing, A. E. Wood and H. E. Wood[161] published a short abstract in which it was stated that study of the rhinoceros has shown it to belong to *Caenopus*, a sensu strictu, an exclusively Oligocene genus, as known at present.

Bowling and Wendler[162] have recently found a fresh-water fauna in the basal part of the Catahoula formation in Fayette County which was studied by MacNeil. Bowling kindly furnished the writer a sketch of the locality, and it was found that the fossils were present in a coarse to conglomeratic sandstone in a small draw in the west-central part of the Wm. Voelkel land within 100 yards of the line between the southeast corner of the E. W. Grau 64.7-acre tract and the northeast corner of the F. Marquart 41.3-acre tract in the southeast part of the James Green Survey, about 1.5 miles west of the Shell Petroleum Company pump station and about 6 miles N. 10° E. of the courthouse at La Grange.

MacNeil[163] has kindly furnished the following information regarding this fresh-water fauna collected by Bowling.

> The fresh-water fauna mentioned by Bowling and Wendler comes from a single locality. The particular report cited by them was my first report based on somewhat fragmentary fossils. Since that time a very fine larger collection from the same locality has been sent me by Mr. Bowling.
>
> I can positively say that the collection was not reworked. The mussels are in most cases preserved in the form of paired valves, in all stages from tightly closed to completely opened. This would hardly be the case with reworked shells.

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[160]Weeks, A. W., Lissie, Reynosa, and upland terrace deposits of Coastal Plain of Texas between Brazos River and Rio Grande: Bull. Amer. Assoc. Petr. Geol., vol. 17, p. 456, 1933.

[161]Wood, A. E., and Wood, H. E., Middle Tertiary vertebrates from the Texas Coastal Plain (abst.): Geol. Soc. Amer., Preliminary List of Titles and Abstracts of Papers to be offered at the 48th Annual Meeting, pp. 69–70, New York, 1935.

[162]Bowling, Leslie, and Wendler, A. P., *op. cit.*, p. 534.

[163]Personal communication from Miss Julia Gardner containing memorandum by Stearns MacNeil, January 8, 1934.

> Since the Tertiary fresh-water faunas are so little known it is impossible to say whether there are similar forms in the Jackson. The fauna contains genera which are not similar to any known forms except those of Catahoula age described by Miss Maury from Rosefield, Louisiana.

The fresh-water fauna in question occurs in a conglomeratic sandstone about 20 feet above the base of the formation. It is evident from the foregoing statement of MacNeil's that there is nothing to indicate that this Catahoula fauna is of Eocene age, and there is no paleontological field evidence available to indicate that any part of the Catahoula formation is Eocene as suggested by Bowling and Wendler.[164] It has been pointed out on page 52 that the marine Jackson fauna identified as Eocene by Miss Julia Gardner and published by Bowling and Wendler is within the Whitsett formation (see section 10, Pl. III) and not in the Catahoula formation. They also refer to a collection near the water tower at Flatonia, which is within the Catahoula outcrop, but no list of species is given.

Oligocene beds have been reported in Mexico, though this Mexican Oligocene may be lower than any Catahoula in this part of Texas, Louisiana, or Mississippi. Miss Gardner[165] states that the Oligocene fossils which she has seen from northern Mexico[166] correlate with the Red Bluff and Vicksburg of the Alabama section.

Moody[167] classified the Catahoula formation as Miocene, and more recently Howe[168] summarized the data pertaining to the age of the Catahoula formation east of Mississippi River and presented evidence pointing to a Miocene age.

The most significant data pertaining to the age of the Catahoula formation have recently appeared as the result of work by S. A. Thompson, Roy T. Hazzard, B. W. Blanpied, Urban Hughes, and J. T. McGlothlin[169] in Clarke, Wayne, and Smith counties,

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[164]Bowling, Leslie, and Wendler, A. P., *op. cit.*, pp. 534–535.

[165]Personal communication.

[166]Böse, Emil, and Cavins, O. A., The Cretaceous and Tertiary of southern Texas and northern Mexico: Univ. Texas Bull. 2748, pp. 114–133, 1927 [1928].

[167]Moody, C. L., Tertiary history of region of Sabine uplift Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 15, pp. 546–547, 1931.

[168]Howe, H. V., Review of Tertiary stratigraphy of Louisiana: Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 635–643, 1933.

[169]Stratigraphy and paleontological notes on the Eocene (Jackson group), Oligocene, and lower Miocene of Clarke and Wayne counties, Mississippi: Shreveport Geol. Soc., 11th Ann. Field Trip, Guidebook, 49 pp., Oct. 5–6, 1934.

Mississippi. It has been discovered by these workers that there are marine strata below the typical Catahoula sands, which on the basis of lithology they divided into three members: the Bucatunna (nonmarine) and the lower and upper Chickasawhay (marine), named in ascending order. The Bucatunna member at the base of this section below the Catahoula truncates the Forest Hill sand, Marianna limestone, Byram marl, and Glendon limestone of the Vicksburg group (Oligocene). Because of this overlap by the Bucatunna member and resulting truncation of underlying Vicksburg strata, which was demonstrated as a result of field work, the rocks above this unconformity (Bucatunna, Chickasawhay, and Catahoula sandstone) have been referred to the Miocene, a conclusion which seems unescapable. The assignment of these rocks to the Miocene is further confirmed by the paleontological work on the Foraminifera, ostracods, and macrofossils by H. V. Howe, James McGuirt, and C. I. Alexander, while M. A. Hanna concedes that though the upper Chickasawhay may be Miocene he regards the lower Chickasawhay and Bucatunna as Oligocene.

These stratigraphic relations in Mississippi have been described in the recent guidebook of the Shreveport Geological Society. A paper by Hazzard and Blanpied is now reported to be in preparation.

At the time this paper is ready for printing, Cooke[170] appears with an article advocating that the Chickasawhay and Bucatunna members of Wayne County, Mississippi, be included in the Byram marl. He also suggests that the Catahoula formation may be older than the Tampa limestone and thus Oligocene in age.

In the same publication is also an article on the subsurface geology of Covington County by George and Bay[171] which is in accord with the surface section described in the guidebook of the Shreveport Geological Society.

In conclusion, therefore, the age of the Catahoula formation in Texas is not conclusively established at present because of the scarcity of fossils. The best surface stratigraphic and paleontologic evidence so far presented in the Gulf Coastal Plain appears

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[170]Cooke, C. W., Notes on the Vicksburg group: Bull. Amer. Assoc. Petr. Geol., vol. 19, pp. 1162–1172, 1935.

[171]George, W. O., and Bay, H. X., Subsurface data on Covington County, Mississippi: Bull. Amer. Assoc. Petr. Geol., vol. 19, pp. 1148–1161, 1935.

to be that obtained from Clarke, Wayne, and Smith counties, Mississippi. Largely on the basis of these data, the author favors tentative assignment of the Catahoula formation of Texas to the Miocene, though it is recognized that beds of Oligocene age may be present in this formation. There is no basis for assigning any of the formation to the Eocene.

DEPOSITIONAL CONDITIONS

The Catahoula formation consists mostly of pyroclastic material. The source and mode of deposition of this material have been a question of speculation among geologists for a number of years, having been discussed in considerable detail by Bailey[172] and later by Plummer.[173] It has been suggested that the material comprising the Catahoula formation came from Trans-Pecos Texas and northern Mexico because in Reeves, Jeff Davis, Presidio, Brewster, Culberson, Hudspeth, and El Paso counties there are Tertiary volcanic rocks varying from acidic to basic with all intermediate types.[174]

From Travis County to Kinney County and especially in Uvalde County there are exposed at a number of places intrusions and extrusions of basalt and associated basic rock described by Lonsdale.[175] They are interbedded with Upper Cretaceous Eagle Ford to Navarro marine sedimentary strata as pointed out by Hill[176] and Getzendaner[177] and therefore are much older than the Catahoula formation and cannot be regarded as volcanoes which contributed material deposited as the Catahoula formation. Eastward downdip along the eastern edge of the Balcones fault zone where many wells have been drilled for oil, basalt and serpentine have been encountered at many places where they are interbedded with Upper Cretaceous sediments. Also the tuffs of the Catahoula are acidic to intermediate, and no basic Catahoula tuffs have been reported.

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[172]Bailey, T. L., *op. cit.*, pp. 154–164.

[173]Plummer, F. B., *op. cit.*, pp. 720–721.

[174]*Idem*, p. 802.

[175]Lonsdale, J. T., Igneous rocks of the Balcones fault region of Texas: Univ. Texas Bull. 2744, 178 pp., 1927.

[176]Hill, R. T., Pilot Knob: a marine Cretaceous volcano: Amer. Geol., vol. 6, pp. 286–292, 1890.

[177]Getzendaner, F. M., Geologic section of Rio Grande embayment, Texas and implied history: Bull. Amer. Assoc. Petr. Geol., vol. 14, pp. 1425–1437, 1930.

———, ———. Mineral resources of Texas: Uvalde, Zavala, and Maverick counties (preprint), Bureau of Economic Geology, 49 pp. 1931.

Baker[178] has pointed out that volcanic ash and its derivatives occur in rocks of the Gulf Coastal Plain from the Woodbine formation (Upper Cretaceous) to the Goliad formation (Pleistocene).

When it is considered that the Catahoula formation or its equivalent is continuous from Mexico to Georgia and contains an abundance of volcanic material throughout the entire area of its outcrop, it is apparent that the source of the material and mode of transportation are not completely explained. It is an interesting fact that the Catahoula formation was deposited as a sedimentary formation at the time of one of the most important periods of volcanism in west Texas as well as in the western United States.

The coarse sands, grits, and conglomerate which comprise the Chita, Dunlap Quarry, and similar beds on the surface probably represent the deposits of a number of coalescing streams on a relatively flat plain. The abundance of well rounded siliceous material testifies that these pebbles in the Catahoula formation were transported a long distance. There are some sand beds in the Catahoula formation containing tuffaceous material associated with the quartz sand in which the material is not so well rounded but which has undergone transportation.

The sudden influx of fluviatile sands with a calcareous matrix is observed in the Catahoula formation in Gonzales and Fayette counties and, as previously pointed out, limestone pebbles 1 inch or more in diameter have been observed in the Chita sandstone in Gonzales County. It is suggested that there was uplift in the region of the present Edwards Plateau and possibly uplift along the Balcones fault line at this time which contributed the lime and limestone pebbles and that the gradients of the streams were increased during the deposition of the Chita, Dunlap Quarry, and similar conglomeratic sandstones. Perhaps the large amount of well rounded siliceous pebbles in these Catahoula sandstones represents the transported products from metamorphic and igneous rocks from the area of the present Llano uplift which was uncovered, together with the material from the weathered cherts, from some of the Cretaceous limestones.

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[178]Baker, C. L., Oral communication.
Bailey, T. L., *op. cit.*, pp. 154–164.

MIOCENE

OAKVILLE FORMATION

NAME AND LITERATURE

Kennedy[179] described the Navasota beds in Grimes and Brazos counties which he divided into an upper and lower division. The lower division included strata from the base of the Wellborn to the base of the Oakville, and the upper division included strata from the upper Catahoula to the top of the Lagarto. (See Pl. I.) The Oakville beds were first differentiated from Penrose's[180] Fayette by Dumble[181] who redescribed these beds several years later. Dumble[182] considered the Oakville as the equivalent of the lower part of the Fleming, a correlation which is doubtless correct. Deussen's[183] first map of the coastal area published in 1912 did not differentiate the Oakville formation but included some of the Oakville in the Fleming clay. His map of 1924 showed the distribution of the Oakville formation southwest of Brazos River.[184] Bailey's[185] description of the Oakville formation in Colorado River valley was about the same as Deussen's, but in southwest Texas Bailey[186] later included the lower part of Deussen's Oakville in the Gueydan formation (Catahoula). Plummer's[187] correlation of the Oakville formation corresponds to that of the more recent authors.

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[179]Kennedy, W., Report on Grimes, Brazos and Robertson counties: Texas Geol. Surv., 4th Ann. Rept., pp. 9–11 and p. 39, 1893.

[180]Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiary of Texas from Red River to the Rio Grande. Texas Geol. Surv., 1st Ann. Rept., pp. 47–50, 1890.

[181]Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geol., vol. 2, pp. 556–559, 1894.

[182]Dumble, E. T., Geology of southwestern Texas. Trans. Amer. Inst. Min Eng., vol. 33, pp. 913–987, 1903.

———, ———, The geology of east Texas: Univ. Texas Bull. 1869, pp. 238–243, 1918.

———, ———, A revision of the Texas Tertiary section with special reference to the oil-well geology of the coast region: Bull. Amer. Assoc. Petr. Geol., vol. 8, pp. 435–436, 1924.

[183]Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Surv., Water-Supply Paper 335, map, 1914.

[184]Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, map, 1924.

[185]Bailey, T. L., The geology and natural resources of Colorado County: Univ. Texas Bull. 2333, pp. 51–66, 1923.

[186]Bailey, T. L., The Gueydan, a new Middle Tertiary formation from the southwestern Coastal Plain of Texas: Univ. Texas Bull. 2645, 187 pp., 1926 [1927].

[187]Plummer, F. B., *op. cit.*, pp. 729–739.

From Grimes County to northern Lavaca County it was possible to separate the lower part of the Oakville from the overlying strata, the former being here designated the lower Oakville. The lower Oakville is shown in the columnar sections on Plates III, IV, and V.

LITHOLOGY

Lower Oakville.—From Grimes County to central Fayette County the strata here designated the lower Oakville consist largely of gray calcareous clay and shale with some thin lenses of cross-bedded calcareous sandstone. The shales are gray and the sandstone lenses are gray and buff. Locally there are beds of reworked shell fragments and non-indurated coquina sands.[188]

In Lavaca and Gonzales counties as well as in southern Fayette County there are greenish clays and tuffaceous sands in the lower Oakville.[189] In this area this unit therefore contains beds of Oakville lithology and Catahoula lithology interbedded.

The matrix of the sands in the lower Oakville is mostly calcium carbonate and the shales are calcareous throughout except that locally beds of greenish tuffaceous shale are present in the southwestern part of the area. (See sections 10, 11, and 12, Pls. III and IV and Pl. V.) The thickness of the unit varies from 60 to 100 feet. Below is a typical section of the lower part of the Oakville formation.

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[188]Typical exposures of the lower Oakville are present at the following localities: along the Anderson-Madisonville State highway No. 90, 1 mile north of Anderson in the south part of the M. D Black Survey, south of the junction of State highway No 90 with the Anderson-Carlos road, Grimes County; along the Navasota-Bryan State highway No. 6, 0.3 mile south of Navasota River on Dr. Emory's 141.5 acre tract, north part of Daniels Arnold Survey, Grimes County; along the Brenham-Somerville State highway No. 36, S. 50° E., 0 75 mile southeast of the junction with the Gay Hill-Clay Creek road, Washington County; along the La Grange-Brenham State highway No. 72, 0.2 mile southwest of Round Top, Fayette County; along the road on south side of and near the southwest corner of F. Fajkus 98.8-acre tract, M. Muldoon Survey, 1.8 miles N. 63° E of Flatonia, Fayette County; in gulleys in the west part of the W. M. Nollkamper 150-acre tract. G. W Cottle Survey, 1.5 miles S. 35° W. of Flatonia, Fayette County.

[189]Good outcrops of this phase of the Oakville are found at the following places: the south part of the J. T. Thompson 265-acre tract. W. P. Stapp Survey, near the south line of the survey, 3.5 miles N. 72° E. of Dilworth; in the southeast part of the G. R. Wright 110-acre tract and adjoining in the southeast part of the J. W. Bailey Estate 540-acre tract, George Blair Survey, 3.2 miles east of Dilworth, Gonzales County.

Section of lower Oakville in bluff on south side of the Navasota River along Bryan-Navasota State highway No. 6, from 0.2 to 0.6 mile southeast of Navasota River on the Dr. Emory 141-acre tract and M. Wood 92-acre tract, D. Arnold Survey, Grimes County.

	Thickness *Feet*
Middle Oakville:	
Moulton sandstone:	
10. Cross-bedded, thin-bedded to massive sandstone, fine to coarse grained; contains no reworked Cretaceous fossils here; grades into beds below. This is the Moulton sandstone of the Oakville formation	10
Lower Oakville:	
9. Calcareous gray to buff shale and sandy shale	6
8. Hard calcareous sandstone	1
7. Soft thin-bedded calcareous sandstone interbedded and interfingering with calcareous shale	9
6. Gray calcareous shale	5
5. Coarse calcareous sandstone, lenticular; probably equivalent of the coquina-like sandstone one-fourth of a mile northeast where fossil bones were collected; coquina rock consists largely of shell and shell fragments	6
4. Gray calcareous shale	38
Total lower Oakville	65
Catahoula formation:	
3. Tuffaceous noncalcareous sand	1
2. Gray noncalcareous clay; gradational below	4
1. Gray and yellowish-green noncalcareous tuffaceous clay	5
Alluvium of Navasota River.	
Total Catahoula formation exposed	10

Southwest of this section in northeastern Washington County is Hidalgo Bluff which marks the southern boundary of Brazos River flood plain. This bluff or its continuation extends across the W. S. Brown, W. & P. Kerr, and E. Clampitt surveys. In this bluff are many good exposures, and the entire bluff section is available for inspection in the vicinity of Hidalgo Church in the W. & P. Kerr Survey where the lower Oakville constitutes the largest part of the section with the Moulton sandstone capping the bluff. The upper part of the Catahoula formation is exposed in the lower part of

the bluff above the river flood plain. Dumble[190] referred to this section and said:

> . . . in Hiladgo Bluff we find overlying the Corrigan [Catahoula], beds which seem clearly referable to the Fleming, and others that are characteristically Oakville.

It is seen from this statement and from Dumble's geologic section at Hidalgo Bluff that he recognized three units in his Hidalgo Bluff section: (1) Corrigan, (2) Fleming, and (3) Oakville, named in ascending order, which are approximately equivalent to (1) the upper part of the Catahoula formation, (2) the lower Oakville member, and (3) the Moulton sandstone of the middle Oakville, following the nomenclature of this report.

Middle Oakville.—The base of the middle Oakville is characterized throughout the area shown on Plate II by a massive cuesta-forming sandstone which varies from 20 to 60 feet in thickness. (See Pls. III, IV, and V.) It is cross-bedded and at many places contains reworked Cretaceous invertebrate fossils. The latter are so well preserved that it is possible to identify many of them. This sandstone contains mostly siliceous fragments consisting of quartz with some jasper and chert and varies in texture from medium grained to grit or fine conglomerate. The matrix is generally calcite. This sandstone forms a most conspicuous topographic feature, and by looking eastward from a place west of its outcrop, the cuesta formed by this sandstone may be seen for 10 or more miles.

This prominent sandstone is here named the Moulton sandstone for the town of Moulton in northwestern Lavaca County which is located on the outcrop. It is well exposed in the vicinity of the church and schoolhouse at the north end of the town. State highway No. 109 from 0.7 mile to 3.3 miles northeast of Moulton is on this sandstone, and along this strip of road the base of the Moulton sandstone is from 0.05 to 0.15 mile west of the highway. Burkett Mound, 1.25 miles N. 40° W. of Moulton, located on the F. C. Kasse 37.6-acre tract, David Burkett Survey, is an outlier formed by the lower part of the Moulton sandstone, which is resistant to erosion, resting

[190]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, pp. 238–240, 1918.

on the beds of indurated clay and sandy clay of the lower Oakville.[191] Some field geologists have mapped the Moulton sandstone as the base of the Oakville.

Bailey[192] gave a good petrologic description of a sample of the Oakville sandstone in the middle part of La Grange bluff south of the town. This sample was probably taken from the Moulton sandstone. The following data are taken from his report.

Table 2. Mineral Composition of Oakville Sandstone in Middle Part of La Grange Bluff.

Mineral	*Per cent*	*Description*
Quartz	31	Colorless glassy grains, many stained, inclusions of apatite, zircon, and titanite suggesting originally present in igneous rock.
Calcite	24	Occurs in (1) transparent crystalline masses in the cement, (2) finely granular concretions, and (3) minute grains intermixed with the clay.
Chert	16	Yellow, black, gray, white, pink, and pale green.
Feldspar	10	Microcline almost as abundant as orthoclase, both generally altered; plagioclase (albite-oligoclase), minor andesine, generally fresh.
Shell fragments	15	
Clay	2	Kaolinite, chlorite, and sericite.
Quartzite	1	Pink to pale gray.
Other minerals	1	Barite, biotite, chalcedony, chlorite, dolomite, epidote, garnet, glauconite, hematite, ilmenite, magnetite, pyrite, rutile, siderite, staurolite, titanite, tourmaline, zircon, *Inoceramus* prisms, and chara seed.
	100	

[191]Representative exposures of the Moulton sandstone also are present at the following localities: 1.85 miles N. 25° W. of Navasota and 0.55 mile S. 30° E. of Navasota River along State highway No. 6 on the Minor Wood 92-acre tract, Daniel Arnold Survey, Grimes County; at Independence, Washington County; on the Brenham-Caldwell State highway No. 36, 1.25 miles southeast of the junction of the highway with the secondary road to Gay Hill station, Washington County; at Round Top on State highway No. 72, Fayette County; capping Obar Hill, 1.3 miles S. 25° W. of Flatonia, Fayette County; at Moulton and northeast along State highway No. 109 in the west part of the Jacob Stemocher 211-acre tract, David Burkett Survey, Lavaca County; in the southeast part of the J. W. Bailey Estate 540-acre tract, George Blair Survey, below U. S. Geological Survey benchmark No. 595 and vicinity, 3 miles S. 83° E. of Dilworth station, Gonzales County.

[192]Bailey, T. L., The geology and natural resources of Colorado County: Univ. Texas Bull. 2333, pp. 62–66 and Table 4, p. 90, 1923.

The Oakville strata above the Moulton sandstone are not shown in the accompanying sections in Plates III, IV, and V, but they consist of sandstones similar in lithology to the Moulton sandstone and are interbedded with clays and shales. The shales are calcareous and the matrix of the sandstones is calcareous, the latter varying from medium-grained to coarse grit.

STRATIGRAPHIC RELATIONS AND THICKNESS

From northeast Grimes County to central Fayette County the character of the material comprising the Catahoula formation and the Oakville formation is very different. The Catahoula formation is green and noncalcareous and the lower part of the Oakville formation is gray and calcareous. As previously mentioned, the contact between these two formations may be easily identified with the aid of hydrochloric acid. At the base of the Oakville formation in many places there is a gray sand generally not more than 2 feet thick. At other places the gray clay of the Oakville formation rests directly on green clay of the Catahoula formation. At some places the contact suggests an unconformity but at other places unconformable relations are not apparent. The columnar sections in Plates III, IV, and V show that less Catahoula strata outcrop in the southwestern part of the area and that the Oakville rests on lower Catahoula beds. As mentioned on a preceding page, the Oakville formation has thus overlapped a large part of the Catahoula formation.

From central Fayette County southward into Lavaca and Gonzales counties the contact between the Catahoula formation and the lower Oakville is more difficult to determine because calcareous sandstones begin to appear in the lower part of the Catahoula formation and the lower Oakville contains greenish clays and tuffaceous sands interbedded with the typical calcareous shales and sands of the Oakville formation. For this reason accurate identification of the Catahoula-Oakville contact as defined in this paper is difficult and in some places impossible, especially in southern Fayette and Gonzales counties. However, the Moulton sandstone which rests on the lower Oakville is a characteristic feature throughout the entire area and may be easily followed.

For the following reasons the contact between the Catahoula and Oakville formations in Grimes, Walker, and Washington counties

is drawn at the position shown in the sections on Plates III and IV rather than at the base of the Moulton sandstone, which has been used by some field geologists: (1) Especially in the northeastern part of the area shown on Plate II, there is a sudden change from the tuffaceous noncalcareous Catahoula clays and sands to the calcareous Oakville clays and sands above at the level indicated in the sections; (2) the sands between the top of the Catahoula formation and the Moulton sandstone (lower Oakville member) contain reworked shell fragments (presumably reworked Cretaceous) and the Catahoula formation below contains none; (3) the truncation of the upper Catahoula strata by the overlying Oakville formation takes place at the base of the lower Oakville and not at the base of the Moulton sandstone (see sections 7 and 8, Pls. III and V); (4) the lithology of the Moulton sandstone apparently marks the presence of a disconformity but it does not appear to record a major unconformity because the lower Oakville member maintains its identity as a separate lithologic unit easily separable from the underlying Catahoula formation as far south as southern Fayette County.

In the central and southern parts of the area at least 100 feet or more of the upper part of the Catahoula formation which is exposed on the surface to the northeast have been removed by erosion. If the Moulton sandstone should be regarded as the base of the Oakville formation there would be no calcareous beds below the Moulton sandstone in northern and central Fayette County, since these calcareous beds, if they were Catahoula, would have been removed by erosion, and the Moulton sandstone would rest directly on the Catahoula formation, a condition which does not obtain as shown by sections 7, 8, and 9, Plate III.

PALEONTOLOGY AND AGE

In 1861 Leidy[193] described vertebrate teeth from Washington County, and in 1863 Shumard[194] called attention to the presence of strata in Washington and adjoining counties consisting of:

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[193]Leidy, Joseph, On fossil teeth from Washington County, Texas: Acad. Nat. Sci. Philadelphia, Proc. 1860, p. 416, 1861.

[194]Shumard, B. F., On the discovery of dicotyledonous leaves in the Cretaceous of Texas: Trans. Acad. Sci. St. Louis, vol. 2, pp. 140–141, 1863.

> . . . calcareous and siliceous sandstones, and white, pinkish and grayish siliceous marls containing water-worn Cretaceous shells in which were well preserved bones . . . closely allied to, or identical with *Titanotherium, Rhinoceros, Equus* and *Crocodilus.*

Dumble[195] collected *Protohippus medius* Cope, *P. perditus* Leidy, *P. placidus* Leidy, and *Aphelops meridianus* Leidy from the Oakville between Oakville and Mikeska. Cope identified this fauna and stated that it represented "Loup Fork" or upper Miocene zone. In reply to a letter of the author's to Walter Granger, G. G. Simpson[196] of the American Museum of Natural History remarked regarding the fauna that "if correctly identified can hardly be anything but upper Miocene."

Two and one-half miles north of Navasota, C. L. Baker[197] collected vertebrate bones of *Merychippus* (horse) cf. *M. seversus* cf. (horse), *Aphelops* sp. (rhinoceros), *Protolabis* or *Procamelus* (camel), *Testudo* (tortoise), and crocodile remains. The bones were examined by Dr. W. D. Matthew who stated that they indicated "middle Miocene, but upper Miocene or lower Pliocene is not excluded." G. G. Simpson[198] writes in regard to this fauna that it is "certainly later than lower Miocene and almost surely older than lower Pliocene. Probably middle and possibly upper Miocene."[199]

Professor Mark Francis of Texas Agricultural and Mechanical College assisted by Professor S. N. Blackberg has been an enthusiastic collector of vertebrates from the Oakville and Lagarto formations for a number of years and has a very complete collection. The collection listed from the J. Garvin farm, 2 miles north of Navasota in Grimes County (see section 3, Pl. III), is in the lower Oakville and corresponds in stratigraphic position with the locality from

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[195]Dumble, E. T., Geology of southwestern Texas: Trans. Amer. Inst. Min. Eng., vol. 33, p. 957, 1903.

[196]Memorandum prepared by G. G. Simpson and contained in letter from Walter Granger to author, January 18, 1933.

[197]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869, p. 237, 1918.
Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Surv., Prof. Paper 126, p. 102, 1924.

[198]*Op. cit.*

[199]R. A. Stirton stated in oral communication to H. B. Stenzel in January, 1936, that the Navasota fauna is approximately equivalent to the Thomas Farm fauna from Florida or possibly a little younger. This would place the Navasota fauna near the boundary between the lower and middle Miocene.

which C. L. Baker collected. O. P. Hay[200] described the following new species from the Garvin farm:

Ameiurus? decorus n. sp. (catfish)	Procamelus concerptus n. sp. (camel)
Tephrocyon scitulus n. sp. (dog)	Procamelus benedentatus n. sp. (camel)
Miohippus blackbergi n. sp. (horse)	*Protolabis francisi n.* sp. (camel)
Miohippus navasotae n. sp. (horse)	Dromomeryx texanus n. sp. (cervid)
Parahippus minutalis n. sp. (horse)	Dromomeryx? angustidens n. sp. (cervid)
Merychippus vellicans n. sp. (horse)	Blastomeryx vigoratus n. sp. (cervid)
Merychippus socius n. sp. (horse)	Merycodus grandis n. sp. (prong buck)

Included with the list of species, Hay described bones from the Lagarto formation. He assumed that only one formation, the Fleming, was represented and stated that "A comparison of the genera and species here described with the lists published in Matthew . . . indicate that the formation from which they came belongs near the top of the upper Miocene or even in the lower Pliocene."

A. E. Wood and H. E. Wood[201] refer to *Merychippus, Aphelops, Protolabis?* or *Procamelus?* and considerable number of other later Miocene forms higher in the formation.

From the foregoing it seems that the Oakville formation should probably be referred to the upper Miocene.

DEPOSITIONAL CONDITIONS

The outcropping Oakville formation is of continental origin and was deposited by a number of coastal streams on a relatively flat plain. The sands are coarser than those in the Jackson group or Catahoula formation with the exception of the Chita, Dunlap Quarry, and unnamed sandstone at the top of the Catahoula formation shown in section 1, Plates III and IV. These streams of Oakville time shifted their channels, redepositing and reworking the sediments many times as shown by the channeling, cross-bedding, and lenticular nature of the sands and clays in the formation. Associated with this drainage system were many mud flats. On this land surface

[200]Hay, O. P., Description of some fossil vertebrates from the Upper Miocene of Texas: Proc. Biol. Soc. Washington, vol. 37, pp. 1–19, 1924.

[201]Wood, A. E., and Wood, H. E., Middle Tertiary vertebrates from the Texas Coastal Plain (abst.): Geol. Soc. Amer., Preliminary List of Titles and Abstracts of Papers to be offered at the 48th Annual Meeting, p. 70, New York, 1935.

carnivorous and herbivorous land animals lived, the bones of which have been found at a number of places.

From northern Fayette County through Grimes County the base of the Oakville formation is marked by the introduction of the first calcareous material which, together with the many reworked Cretaceous fossils, indicates uplift in the region of the present Edwards Plateau and Llano uplift. As pointed out on a preceding page, this introduction of calcareous material from Fayette County southward began during Catahoula time, indicating that this uplift in at least part of central Texas was initiated or rejuvenated in Catahoula time and that by the end of Catahoula time it was so widespread that detrital material from the area was being contributed over a wide area extending from east Texas to the Rio Grande. The increasing amount of coarse material in the Oakville formation in that part of the Gulf Coastal Plain shown in Plate II as compared with the Catahoula formation suggests an increase in stream gradient.

In the northeastern part of the area (see Pl. II), ash and other volcanic material were not contributed to the Oakville formation except as reworked Catahoula material, but in the southern part of the area fresh volcanic material continued to be deposited in the lower Oakville member.

Apparently this uplift of the Edwards Plateau and Llano region was rapid and the rocks did not undergo complete weathering as indicated by the presence of orthoclase and microcline feldspar.[202] Though a considerable part of the latter minerals is somewhat weathered, Bailey states that the plagioclase feldspar (albite and oligoclase with minor andesine) in the Oakville formation is generally fresh, and since he[203] reports albite-oligoclase feldspar as the principal feldspar constituent of the Catahoula (Gueydan) formation, it appears likely that the latter feldspar at least in part may have been derived from the Catahoula formation.

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[202]Bailey, T. L. The geology and natural resources of Colorado County: Univ. Texas Bull. 2333, p. 64, 1923.

[203]Bailey, T. L., The Gueydan, a new Middle Tertiary formation from the southwestern Coastal Plain of Texas: Univ. Texas Bull. 2645, p. 120, 1926 [1927].

STRUCTURE

REGIONAL STRUCTURE

BRAZOS RIVER SYNCLINE

Plates III and IV, the former with the base of the Catahoula formation as datum and the latter with the base of the Oakville formation as datum, show that in the area in the vicinity of Brazos River the Jackson group has a thicker section than the country to the northeast or southwest and is therefore lower structurally than any part of the area. This structural feature is here designated the Brazos River syncline. Northeastward the Jackson group on the outcrop is thinner than in the center of the Brazos River syncline, and southwestward towards Flatonia the Jackson section gradually decreases in thickness. Also towards this latter direction the Catahoula formation from eastern Grimes County decreases from 250 to 55 feet in thickness, the decrease being due all or in part to overlap. The Clay Creek salt dome in northern Washington County is approximately in the center of this syncline where the Jackson group and Catahoula formation attain their maximum thicknesses.

The Brazos River syncline apparently extends 30 miles or more southeastward down Brazos River, which is shown by the fact that downdip in wells in the vicinity of the Raccoon Bend oil field the subsurface geology shows that the Jackson strata change in strike from N. 36° E. southwest of the field to N. 65° E. northeast of the field forming a syncline in which is located the uplift giving rise to the Raccoon Bend oil field[204] in Austin County. Farther down the Brazos Valley in Waller County apparently in this same structurally low area is the San Felipe salt dome.

FLATONIA NOSE

There is a regionally high area extending across the outcrop of the Jackson group and Catahoula formation from central Fayette County into Gonzales County. (See Pls. III and IV.) This regional feature is here designated the Flatonia nose. It is shown by thinned outcrop sections of these strata. The Jackson section at the surface is thinner on this nose than toward the northeast. (See Pls. III, IV,

[204]Teas, L. P., and Miller, C. R., Raccoon Bend oil field, Austin County, Texas. Bull. Amer. Assoc. Petr. Geol., vol. 17, p. 1472, 1933.

and V.) Apparently this is due to gradual uplift with diminished deposition during Jackson time. Only the lower part of the Catahoula formation is exposed across this nose; if the upper Catahoula strata were deposited they have since been eroded and the overlapping Oakville formation deposited on the lower part of the Catahoula formation.

Although sufficient subsurface data are not available to the author to establish the following point, it is possible that this nose may extend northwestward and in some way be related to the San Marcos arch[205] in Caldwell and Guadalupe counties where the Luling, Salt Flat, and Darst Creek oil fields are situated and the Edwards limestone is regionally high with respect to the area to the northeast and southwest.

The base of the Chita sandstone of the Catahoula formation has an approximate surface elevation of 350 feet in eastern Grimes County, 300 feet in southern Brazos County, 350 feet in north-central Washington County, 410 feet in west-central Fayette County, and 450 feet in northeastern Gonzales County. These present surface elevations may conform in a general way to the Brazos River syncline and Flatonia nose, but the lower elevations in the Navasota and Brazos river valleys and their tributary valleys are in part, at least, accounted for by the drainage lines.

LOCAL STRUCTURES

CLAY CREEK SALT DOME, WASHINGTON COUNTY

Location and history.—The Clay Creek salt dome is located in north-central Washington County about 3 miles west of Independence and 4½ miles N. 50° E. of Gay Hill station on the Santa Fe Railroad. The central part of the dome is mostly in the G. F. Perry League. This dome was discovered by W. B. Ferguson in July, 1926, for the Sun Oil Company while mapping the surface geology of Washington County. The geology of this dome has been described by Heath, Waters, and Ferguson[206] and has been discussed

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[205]Adkins, W. S., The Mesozoic systems in Texas, *in* The Geology of Texas, Vol. I, Stratigraphy: Univ. Texas Bull. 3232, p. 266, 1932 [1933].

[206]Heath, F. E., Waters, J. A., and Ferguson, W. B., Clay Creek salt dome, Washington County, Texas: Bull. Amer. Assoc Petr. Geol., vol. 15, pp. 43–60, 1931.

by Lahee.[207] As this report is ready for printing, another paper by Ferguson and Minton[208] bringing the data on this structure up to date has just appeared. The following information pertaining to this dome has been obtained from these papers and by personal communication with the authors.

Surface geology.—Ferguson's map accompanying his latest paper shows that the surface distribution of the normal outcrop pattern has been greatly deformed as a result of the salt movement. The geology of the Clay Creek dome shown on Plate II of this report was furnished the author in 1933 by Mr. Ferguson. The Caddell formation, the zone of *Textularia dibollensis* Cushman and Applin, crops out at approximately 1000 feet above its normal position in an area where normally the Catahoula formation is expected at the surface. Likewise the Oakville, the youngest formation exposed, crops out over the central part of the dome and is about 500 feet below its normal position.

Subsurface geology.—Because of the fact that all leases on this dome were drilled by one company, which has carefully cored and sampled all wells, it has been possible for the Sun Oil Company geologists and palenotologists to work out probably the most complete depositional history yet recorded on any salt dome in Texas.

From oral discussion with Ferguson and from the recent paper by Ferguson and Minton the following geologic history of the dome is obtained. There are no data regarding pre-Midway (pre-Eocene) salt movement, but the absence of the Midway or older formations over the cap indicates non-deposition or removal by erosion of the latter formation. The upthrusting movement was vigorous and consistent prior to the beginning of Wilcox (Eocene) time and continued to the end of middle Wilcox time. From then until the end of upper Wilcox deposition the upthrust was retarded and there was settling in the central area. The upthrusting continued with varying degrees of intensity through Claiborne (Eocene) time as shown by the differences in thicknesses of the Carrizo, Reklaw,

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[207]Lahee, F. H., Clay Creek salt dome, Washington County, Texas: Bull. Amer. Assoc. Petr. Geol., vol 15, pp. 279–283 and pp. 1113–1116, 1931.

[208]Ferguson, W. B., and Minton, J. W., Clay Creek salt dome, Washington County, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 20, pp. 68–90, 1936.

Queen City, Weches, Sparta, Crockett, and Yegua formations. During Jackson (Eocene) time there was apparently little upward movement of salt as fairly complete sections of the Caddell, Wellborn, Manning, and Whitsett formations were deposited. However, following the Jackson epoch there was upthrust and erosion of the dome as shown by the fact that the Catahoula (Miocene?) formation rests on all formations of the Jackson (Eocene) group from the Whitsett to the Caddell inclusive. (See section 4, Pls. III and IV of this report and fig. 9, p. 88, of Ferguson and Minton's paper.)

During Catahoula time there was considerable downwarping since the central part of the dome has 700 feet of Catahoula strata, which is about 400 feet more than is known elsewhere in the region. (See section 4, Pls. III and IV.) Downwarping continued throughout Oakville deposition since there are 400 feet of Oakville strata in the central part of the dome where the Catahoula formation should normally be at the surface.

Production and development.—Production on this dome is obtained from the Wilcox formation and the following formations of the Claiborne group: Queen City, Sparta, and lower part of the Yegua. The Queen City formation has been the most important producing zone up to the present. The producing wells vary from 1154 to 1560 feet in depth, with initial production ranging from 100 to 6800 barrels per day. The Sun Oil Company No. 2 G. F. Grote, total depth 2904 feet, encountered the top of the lime cap at 2200 feet, the top of the anhydrite at 2354 feet, and the top of the salt at 2854 feet, the latter extending to the total depth of 2904 feet. The discovery well of this field was the Sun Oil Company No. 1 G. F. Grote, total depth 1154 feet, which was completed October 10, 1928, as a 125-barrel well making 25° Bé. oil. Up to November, 1935, this field had produced over 3,092,000 barrels from about 250 productive acres. Seventy-seven wells have been drilled, thirty-six of which were productive oil wells and five productive gas wells. Eight formerly productive oil wells and one productive gas well have been abandoned. Twenty-eight dry holes were drilled during exploration, at least five of which penetrated salt. The daily production is about 750 barrels. Most of the oil is 26° Bé. but a few wells produce 17° Bé. and one 32° Bé. oil.

FERGUSON CROSSING DOME, BRAZOS AND GRIMES COUNTIES

Location and history.—During the winter of 1928, Mr. Walter Smith of The Texas Company found some evidence of structure along Navasota River about 7 miles N. 60° E. of Wellborn station and that company took leases on several tracts of land. Later in the same year Mr. Herbert J. Weeks of the Sun Oil Company investigated the same area, and the Sun Oil Company leased several tracts on the west side of the river. At that time most of the leases on the east side of the river in Grimes County were understood to have been held by individuals in a drilling block.

In the spring of 1929 a refraction seismograph party of the Humble Oil and Refining Company located a salt dome in the vicinity of old Ferguson Crossing on Navasota River for which locality this prospect is named. This discovery was subsequently checked with seismograph by one or more companies. The Humble Oil and Refining Company acquired a considerable block of leases in the George W. Seaton, George Mason, U. F. Case, T. Boatwright, B. B. B. & C. Railroad Company, west part of the Amos Gates, and west part of Joseph T. Robinson surveys in Grimes County and the remaining available acreage west of the river in Brazos County not held by the Sun Oil Company and The Texas Company located in the Chas. Sherman, P. Rector, A. Walsch, J. S. Korminski, and east part of the A. Williams tracts.

Surface geology.—The surface outcrop pattern of the Ferguson Crossing dome is not as complicated as that of the Clay Creek dome in Washington County. At the Ferguson Crossing dome there are several localities of steep dips, and the Bedias sandstone which fringes the structure on the east and south sides seems to have been displaced at some places by faulting, probably as a result of salt intrusion, and is present about 1 mile northwest of its normal position along the Wellborn-Keith road on the north line of the Perry Parnell Estate 100-acre tract, where it strikes N. 55° E. and dips 88° southeast. The Bedias sandstone on the east and southeast sides of the structure in the southwest corner of the J. T. Robinson and southeast corner of the C. W. Seaton surveys dips southeast, east, and northeast from 5° to 15° at a number of places. Adjoining Navasota River in a bluff on the H. Mitchell Estate 200-acre tract is

an outcrop of rock with strike varying from N. 10° W. to N. 25° E. and dipping 5° to 15° eastward.

West of Navasota River in Brazos County along the edge of the flood plain about 3500 feet northeast at right angles to the southwest line and about 4000 feet southeast at right angles to the northwest line of the A. C. Williams 563-acre tract, J. Gordon Survey, is an outcrop of semi-quartzitic Bedias? sandstone with the following variation in strike and dip: from N. 40° W., dip 23° northeast, to N. 60° W., dip 35° southwest.

The central part of the uplift in Grimes County is largely covered with terrace deposits, and there is a wide alluvium-filled flood plain adjoining Navasota River in Brazos County so that exposures are scarce. It is, therefore, unknown if any Yegua strata are uplifted to the surface on any part of the dome, though this is possible. However, the two wells drilled by the Humble Oil and Refining Company entered the Caddell formation below the surface gravels. (See table 3, p. 91.)

Subsurface geology.—Two wells have been drilled on this structure by the Humble Oil and Refining Company.[209] The Ward Templeman No. 1, total depth 4170 feet, completed November 6, 1933, is reported by L. P. Teas to have encountered Reklaw from 2601 to 3207 feet; from 3227 to 3542 feet the identity of the formation was indeterminate, but it is believed that the formation just above the cap was probably Reklaw or Queen City. The log shows hard sand and lime from 3640 to 3820 feet, anhydrite and lime from 3820 to 3830 feet, anhydrite from 3830 to 4038 feet, and salt from 4038 to the total depth of 4170 feet.

The Humble Oil and Refining Company Mary R. Henderson was completed November 19, 1933, as a dry hole at 6131 feet in shale without penetrating any salt. In this well the Wilcox formation was reached at 3000 feet and persisted to 5893 feet; the formation between 5893 and 6131 feet is uncertain. No shows of oil or gas were reported in either well.

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[209]The subsurface data regarding the formations penetrated on the Ferguson Crossing dome have been furnished by L. P. Teas of the Humble Oil and Refining Company in letter of June 26, 1934.

Table 3. Summary of Subsurface Data* on Humble Oil & Refining Company Wells at Ferguson Crossing Dome, Grimes County.

Humble Oil & Refining Company No. 1 Ward Templeman: located 200 feet south and 200 feet east of the northwest corner of Ward Templeman 71.7-acre tract, George W. Seaton Survey; elevation of derrick floor 208 feet; total depth 4170 feet; completed November 6, 1932. Well No. 1, Plate VI.

Humble Oil & Refining Company No. 1 Mary R. Henderson: located 750 feet south and 700 feet west of the northeast corner of Mary R. Henderson 158.6-acre tract, George W. Seaton Survey; elevation of derrick floor 226 feet; total depth 6131 feet; completed January 31, 1934. Well No. 2, Plate VI.

	Base of surface sand	First Caddell, lower part of formation; Textularia dibollensis	Top Yegua formation	First Eponides yeguaensis	Top Crockett (Cook Mountain); first Certabulimina eximia	Top Operculina zone of Crockett	Top Weches	Top Queen City	Top Reklaw	Top Carrizo	Top Wilcox formation	Top anhydrite	Top salt
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Humble Oil & Refining Co. No. 1 Ward Templeman	83	83	114	1131	1314	1618	2057	2240	2640	2887?	2960?	3830	4038
Humble Oil & Refining Co. No. 1 Mary R. Henderson	75	75	120	1140	1200	1620	2000	2200	2600	2860?	2925?†		

*Paleontology by John R. Sandidge and well log correlation.

†The samples on this well show sand, shale, and lignitic material to the bottom of the hole and it seems possible that the Wilcox formation persisted to the total depth of 6131 feet. If this correlation is correct the Wilcox was dipping very steeply or was deposited in a rapidly subsiding depression on the flank of the dome to account for this abnormal thickness.

MILLICAN FAULT, BRAZOS AND GRIMES COUNTIES

Location and history.—Northeast of the town of Millican in southern Brazos County and extending into Grimes County there is a fault which the writer has designated the Millican fault. This fault was discovered during the course of field mapping of Brazos County for the Shell Petroleum Corporation in March, 1928. The fault extends in a northeast-southwest direction across the H. Evans Association, A. Millican Survey and T. H. Mays Survey in Brazos County and Hanna Cornaugh Survey in Grimes County with the strike varying from N. 65° E. to N. 75° E. As a result of this work the Shell Petroleum Corporation acquired a block of leases covering a portion of the structure in Brazos County. About June, 1930, the Humble Oil and Refining Company acquired a block of leases in the Hanna Cornaugh and Wm. Saunders surveys in Grimes County. (See Pl. VI.) The structure of southern Brazos County has been reëxamined in detail since that time.

The Millican fault, or another fault *en échelon* with it, extends southwest of the village of Millican across the E. M. Millican, Wm. Devers, and Walter Southerland surveys. On the basis of surface geology done in 1929 by the author, the Shell Petroleum Corporation leased a considerable block in the Southerland, Millican, and Devers surveys.

Surface geology.—The upthrown side of the Millican fault is on the southeast and the downthrown side is on the northwest. The maximum displacement east of the Southern Pacific Railroad is apparently on the K. T. Williams 290-acre tract, H. Evans Association, A. Millican Survey, and northeastward in the Ward Templeman 1523-acre tract, T. H. Mays Survey. (See Pl. VI.) In this area of greatest surface displacement, the chocolate-colored clays and sands of the Manning formation above the Dilworth sandstone on the upthrown side are in contact with the Dunlap Quarry sandstone on the downthrown side, indicating a surface displacement of about 200 feet. (See Pl. VI.) The Yuma sandstone in the upper part of the Manning formation (see Pl. VI and p. 36) outcrops on the upthrown side of the fault. East of Navasota River on the Annie B. Foster 1194-acre tract the distribution of the surface beds is not apparent due to the alluvium of the flood plain and a heavy cover of terrace deposits on the adjoining hills.

Southwestward from the southwest corner of the K. T. Williams 290-acre tract the Whitsett formation on the upthrown side comes into contact with the downthrown Catahoula forming the southwest closure. The closure on this fault is also demonstrated by the surface distribution of the Yuma sandstone. (See Pl. VI.) To the northeast in Grimes County the upthrown Whitsett and Catahoula formations come into contact with the downthrown Catahoula formation in an area largely covered by terrace sands. However, the northeast closure is confirmed by the trend of the surface trace of the fault which is N. 70° E., while the average regional strike of the rocks northeast of the fault is about N. 50° E. (See Pl. VI.)

Disturbed beds in the vicinity of the fault plane are exposed in a small gully about 3500 feet west of the east line of the H. Evans Association, A. Millican Survey and about 400 feet north of the south line of the K. T. Williams 290-acre tract. The best exposure of the fault plane is on the Ward Templeman 1523-acre tract, T. H. Mays Survey, in a small gully between 100 and 300 feet northeast of the Humble Oil and Refining Company pipeline where the strike was observed to be N. 75° E. and the dip 65° northwest. This gully crosses the pipeline at a point about 2750 feet southeast of the place where the pipeline crosses the west line of the T. H. Mays Survey. At both of the exposures referred to above, the chocolate-colored shales of the Manning formation below the Yuma sandstone on the upthrown side are in contact with the Dunlap Quarry sandstone on the downthrown side, the latter forming a prominent ridge.

West of the Southern Pacific Railroad the Millican fault, or another *en échelon* fault, continues southwestward, and in the north part of the E. M. Millican Survey and in the Wm. Devers Survey the structure again shows increased surface displacement bringing the Manning formation to the surface on the upthrown side with the Catahoula formation on the downthrown side. The surface trace of the fault across the E. M. Millican and Wm. Devers surveys was not found because of the cover of terrace gravels, but the trace is approximately located by mapping the isolated outcrops of the several formations which are exposed in the drainage lines and which show a repetition of section.

Downdip from the Millican fault in the Wm. Devers and E. M. Millican surveys there are at least two faults striking N. 10° to

25° E. downthrown on the northwest side which are associated with the deformation that produced the Millican fault. The surface distribution of the formations is shown on Plate VI.

The southwestern continuation of the Millican fault cannot be followed across the alluvium filled flood plain of Brazos River but *en échelon* faults along this same general trend continue into Burleson County as shown by the faulting northeast of Clay station on the Stone farm in the J. Fisher Survey.

Subsurface geology.—The Shell Petroleum Corporation after drilling several core tests to the Caddell formation, information on which is not available, traded a portion of their leases east of the Southern Pacific Railroad in the T. H. Mays and H. Evans Association, A. Millican surveys to Atkins and O'Neil in consideration of drilling a 3500-foot well. The latter sold some of their acreage and contracted the drilling of this well to W. J. Walton of San Antonio. The well was spudded November 25, 1932, and completed on February 2, 1933.

The Atkins and O'Neil No. 1 K. T. Williams well, total depth 3511 feet, was drilled on the K. T. Williams land 620 feet north of the K. T. Williams 290-acre tract and 320 feet west of the east line of the H. Evans Association, A. Millican Survey. The well was located about 1520 feet northwest of the surface trace of the fault and apparently cut the fault in the Yegua formation as shown by the fact that the Yegua formation is 894 feet thick as compared with the normal thickness of 1150 feet found in Atkins and O'Neil No. 1 Clay Estate. (See Pl. VII and table 4, p. 97.) The subsurface data suggest that the fault plane of the Millican fault may dip about 45° northwest, although the dip at the surface reaches a maximum of 65° northwest. From 3392 to 3464 feet a soft sand in the Queen City was encountered in the Williams well. A drill stem test showed warm salt water and a faint show of gas.

Prior to drilling, the surface throw of the Millican fault was calculated as approximately 200 feet, and this figure checked fairly well with the subsurface data as recorded by paleontological determination of the contacts which are shown in table 4. It is believed that the Atkins and O'Neil No. 1 Clay Estate located to the southwest in Brazos County had a normal section from the Caddell formation to the bottom of the hole.

Table 4. Amount of Displacement on Millican Fault as Indicated by Subsurface Data. Based largely on micropaleontology by Shell Petroleum Corporation.

	Top of Caddell to top of Cook Mountain	Top of Yegua to top of Operculina zone of Crockett	Top of Yegua to top of Weches	Average throw of fault
	Feet	*Feet*	*Feet*	*Feet*
Atkins & O'Neil No. 1 Clay Estate; Brazos County. Well No. 8, Plate VI. Normal section	1268	1431	1924	
Atkins & O'Neil No. 1 K. T. Williams; Brazos County. Well No. 9, Plate VI. Shortened section	1042	1236	1705	
Amount of shortening of section	226	195	219	220

A summary of the micropalcontology of the Atkins & O'Neil No. 1 K. T. Williams well follows.

Table 5. Micropaleontologic record of Atkins & O'Neil No. 1 K. T. Williams. Located 620 feet north of north line of K. T. Williams 290-acre tract and 320 feet west of east line of H. Evans Association, A. Millican Survey, Brazos County. Elevation 235 feet; total depth 3511 feet; commenced November 25, 1932; completed February 2, 1933. The well began in the Catahoula formation below the Dunlap Quarry sandstone. Well No. 9, Plate VI.

Source of information	Top of Caddell (Textularia dibollensis)	Top of Yegua (Cockfield)	Top of Crockett (Cook Mountain)	Top of lower Saline Bayou	Top of Operculina zone of Crockett (top of Weches of Sun Oil Co.)	Top of Weches	Top of Queen City
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Shell Petroleum Corporation	1096	1232	2138		2468	2937	3157
Sun Oil Company	1123	1225	2118		2448		
Humble Oil & Refining Company	1154	1254		2138	2468		
United Gas Company		1254	2148			2947	

The Shell Petroleum Corporation cored their block of leases in the Walter Southerland and Wm. Devers surveys to the Caddell formation and established the presence of the extension of the Millican fault and other associated faults. The detailed data on this coring are not available. That company traded a portion of their leases to Atkins and O'Neil and the latter contracted a well to W. J. Walton which was located on the lands of the Clay Estate in

the Walter Southerland Survey. This well was spudded and completed early in 1933.

The Atkins and O'Neil No. 1 Clay Estate well apparently cut the fault above the Caddell formation since there seems to be no shortening of section below the top of the Caddell. Atkins and O'Neil No. 1 Clay Estate though slightly updip seems to be structurally higher than the K. T. Williams No. 1 as shown by a comparison of the paleontological records in tables 5 and 6. The Clay Estate well entered the Caddell formation at a depth of 558 feet as compared with 1096 feet in the K. T. Williams well, the latter apparently being a downthrown well at this point.

The Atkins and O'Neil No. 1 Clay Estate well was abandoned at a total depth of 3534 feet without encountering any shows of oil or gas.

A summary of the paleontology of the Atkins and O'Neil No. 1 Clay Estate well is shown in table 6.

Southwestward in Burleson County in the vicinity of some faults on the *en échelon* projection of the Millican trend, several wells have been drilled in the P. Singleton and J. Fisher surveys. (See Pl. VI.) The micropaleontological data on these wells as determined by micropaleontologists of several companies have been furnished by Messrs. Heber Stone and Albert Stone of Brenham, on whose land one of these wells was drilled. A summary of the micropaleontological and correlation data on these wells is given in table 7. The micropaleontological data in regard to the three wells of the Sansom Oil Company are somewhat fragmentary.

Few cores were taken in the Sansom Oil Company No. 1 Duckworth well so far as the records show, and the correlation points given in table 7 must be accepted with reservation. Nevertheless the most likely correlation points with the data at hand are suggested in table 7. Assuming that these points are approximately correct, it appears that the Sansom Oil Company No. 1 Duckworth was a downthrown well as far as the top of the Yegua formation with respect to the Mid-South No. 1 Duckworth and Gilley to the south. If the determinations are approximately correct, the interval from the top of the Yegua formation to the top of the Sparta formation in the Sansom Oil Company No. 1 Duckworth is 1436 feet as compared with 1567 feet in the Stone Estate No. 1 Stone Fee and 1559 feet in the Mid-South No. 1 Duckworth and Gilley,

Table 6. Micropaleontologic record of Atkins & O'Neil No. 1 Clay Estate. Located 1150 feet east and 5775 feet north of southwest corner of Clay Estate 4394-acre tract, Walter Southerland Survey, Brazos County. Elevation 190 ± feet; total depth 3534 feet; commenced February 17, 1933; completed March 27, 1933. The well began in alluvium probably underlaid by the Manning formation of the Jackson group. Well No. 8, Plate VI.

Source of information	Top of Caddell (Textularia dibollensis)	Top of Yegua (Cockfield)	Top of lower Saline Bayou	Top of Cook Mountain	Top of Operculina zone (Shell Corp.); top of Crockett (Humble Co.)	Top of Sparta	Top of Weches	Top of Queen City	Top of Reklaw	Top of Carrizo-Wilcox
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Shell Petroleum Corporation	558	676		1826	2107		2600	2840	3190	3445
Humble Oil & Refining Company	584	676	1700		2107	2200	2530	2700	3200	

Table 7. Subsurface Data of Wells Northeast of Clay Station in Burleson County.

Abbreviations used in this table are as follows: *, correlation point suggested by driller's log; H, paleontology by Humble Oil & Refining Company; S, paleontology by Sun Oil Company; Sh, paleontology by Shell Petroleum Corporation. An asterisk with company letter indicates correlation point determined from driller's log supplemented by paleontology where samples were not sufficiently close together for the exact micropaleontological correlation point to be determined.

	Top of Caddell *Feet*	Top of Yegua *Feet*	Top of Crockett *Feet*	Top of Operculina zone of Crockett *Feet*	Top of Sparta *Feet*	Top of Weches *Feet*	Top of Queen City *Feet*	Top of Reklaw *Feet*	Top of Carrizo *Feet*	Top of Wilcox *Feet*
Stone Estate No. 1 Stone Fee; approximately 5400 feet NE, 3300 NW of S corner of J. Fisher Survey; elevation 210 feet, estimated; total depth 4494 feet. Well No. 7, Plate VI.	660*?	784* (S)	1868*	2245 (S)	2351* (H)	2635* (H)	2850 (H)	3200*?	None	3543 (H)
Mid-South No. 1 Duckworth and Gilley; 12248 feet S. 45° 40′ W of NE corner of P. Singleton Survey, thence 1615 feet S. 31° 40′ E or about 700 feet S-SE of Sansom Oil Company No. 1 Duckworth (and Gilley) and about 200 feet NW of Sansom Oil Company No. 2 Duckworth. Well No. 4, Plate VI.	790*	919 (Sh & H)	2006* (Sh & H)	2359* (Sh & H)	2478*					

	Top of Caddell *Feet*	Top of Yegua *Feet*	Top of Crockett *Feet*	Top of Operculina zone of Crockett *Feet*	Top of Sparta *Feet*	Top of Weches	Top of Queen City *Feet*	Top of Reklaw *Feet*	Top of Carrizo *Feet*	Top of Wilcox *Feet*
Sansom Oil Company No. 1 Duckworth (and Gilley); 5660 feet NE and thence 1430 SE of S corner of J. Fisher Survey; approximate elevation 206 feet; total depth 2670 feet. Well No. 6, Plate VI.	885*?	1009*? (H) (Fault ?)	1985*?		2445* (H)					
Sansom Oil Company No. 2 Duckworth (and Gilley); about 200 feet S-SE of Mid-South No. 1 Duckworth and Gilley; approximate elevation 206 feet; total depth 3014 feet. Well No. 3, Plate VI.			2010*		2494*	2760*				
Sansom Oil Company No. 3 Duckworth (and Gilley); about 300 feet W-SW of Mid-South No. 1 Duckworth and Gilley; approximate elevation 206 feet; total depth 2652 feet. Well No. 5, Plate VI.			2015*		2495*					

indicating that the Yegua-Sparta interval was possibly shortened 130 feet, more or less, by a fault. If a fault is present, the Mid-South No. 1 Duckworth and Gilley and the Sansom Oil Company Nos. 2 and 3 Duckworth must have crossed this probable fault above the top of the Caddell formation. A fault would account for the reported shows of oil and gas in the wells on the Duckworth and Gilley land. It is impossible to see any evidence of a fault on the surface in the alluvium filled valley where these wells are located.

SINGLETON FAULTS

Northeast of Singleton in Grimes County there are several faults which extend for at least 7 miles northeastward to the Walker County line. These faults are present across the Cyrus Campbell, T. C. Varner, B. B. B. & C. Railroad Company, the two W. C. J. Hill, northwest part of G. W. Robinson, J. Whitley, S. Walker, H. Hyland, F. M. Davis, and adjoining surveys. This belt of faulting which is from 2 to 2½ miles wide appears to be complicated at the southwest end by from four to six small faults which apparently converge to the northeast, and in that part of the area there appear to be two principal faults, downthrown to the northwest.

The southernmost of these faults which repeats the Chita sandstone extends northeastward from the central part of the Cyrus Campbell Survey across the northwest part of the John Fisher Survey and southeast corner of the John Whitley Survey into the extreme southern part of the S. Walker Survey.

Two wells have been drilled in the northern part of this faulted belt but no shows of oil are reported in either. The best available information on these wells is given in table 8 on page 101.

OTHER FAULTS

At a number of localities there are minor faults within the outcrop of the Jackson group in Grimes, Brazos, Washington, and Fayette counties, but in general they do not show any surface closure and the amount of throw is 50 feet or less. It is not within the scope of this paper to describe these small structural features.

Table 8. Summary of Subsurface Data on Recent Wells Northeast of Singleton, Grimes County.

Clark & Cowden Drilling Corporation (Russ Petroleum Company) No. 1 Grimes Brothers: located 330 feet from southwest line and 990 feet from northwest line of Grimes Brothers 406-acre tract. H. Hay Survey; elevation of derrick floor 316 feet; total depth 3505 feet; completed April 10, 1935.

Jordan & Wallace No. 1 Henderson: located 150 feet southwest and 150 feet southeast of northeast corner of R. L. Henderson 40-acre tract, B.B.B. & C. Railroad Company Survey (Miles H. Taylor Survey); elevation of derrick floor 349 feet; total depth 3521 feet; completed August 27, 1935.

Abbreviations used in this table are as follows: M. contact based on micropaleontology by Magnolia Petroleum Company; U. contact based on micropaleontology by United Gas Company; L.C., contact based on correlation of driller's log.

	Top of Caddell (Textularia dibollensis) *Feet*	Top of Yegua *Feet*	Top of Cook Mountain (first Certabulimina eximia) *Feet*	Top of Operculina zone of Crockett *Feet*	Top of Weches *Feet*	Top of Queen City *Feet*	Top of Reklaw *Feet*	Top of Wilcox *Feet*
Clark & Cowden No. 1 Grimes.*	560–90 in formation (M)	Not recorded	1730–60 (M)	Not recorded	2430–50 (M)	2655 (L.C.)	3002 (M)	3380 (M & L.C.)
Jordan & Wallace No. 1 Henderson.*	872–92 (U)	936–59 (U)	2052–74 (U)	Not recorded	2800 ± (L.C.)	3010 ± (L.C.)	3350 ± (L.C.)	

*Most of the contacts in these wells were not cored and the contacts were determined by micropaleontology from well cuttings supplemented by correlation of the driller's log and should therefore be accepted with some reservation.

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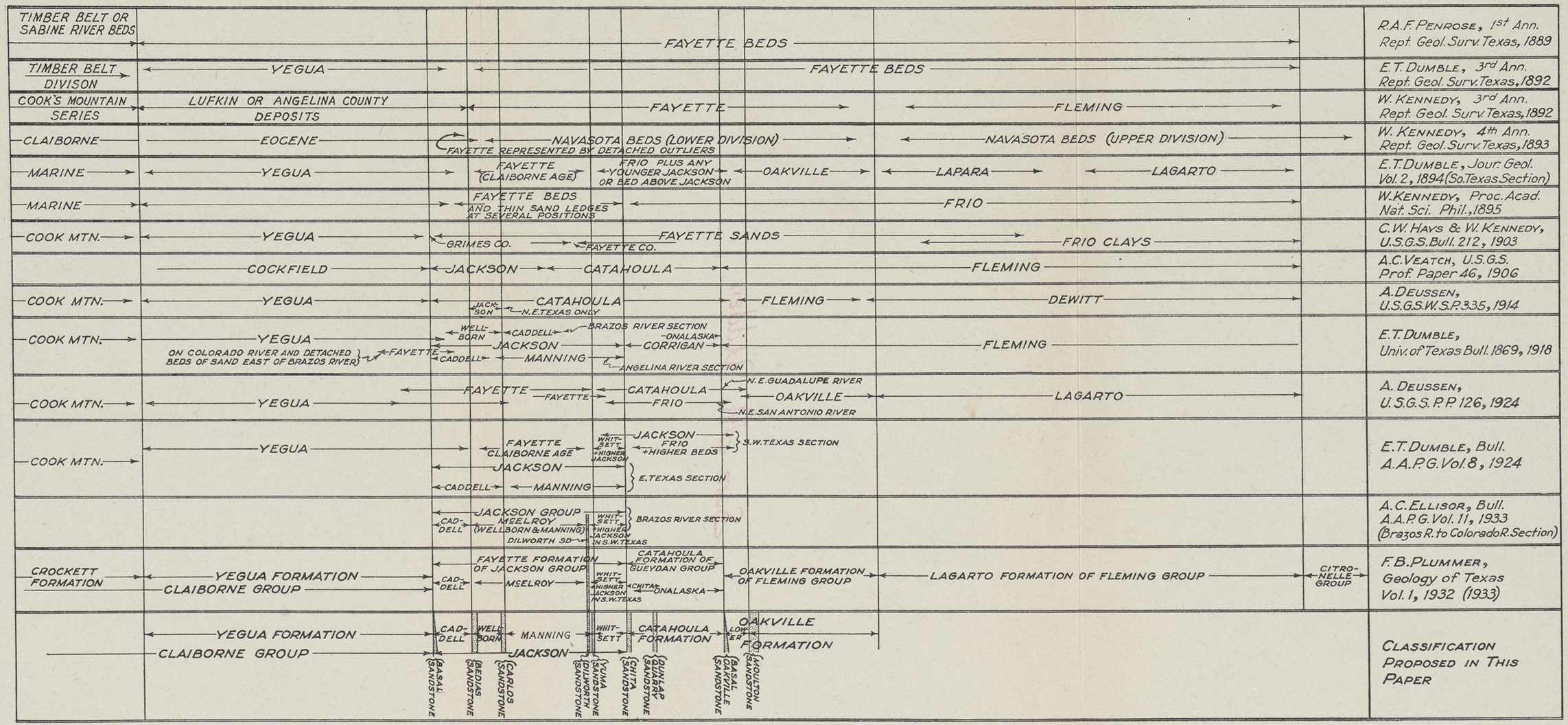
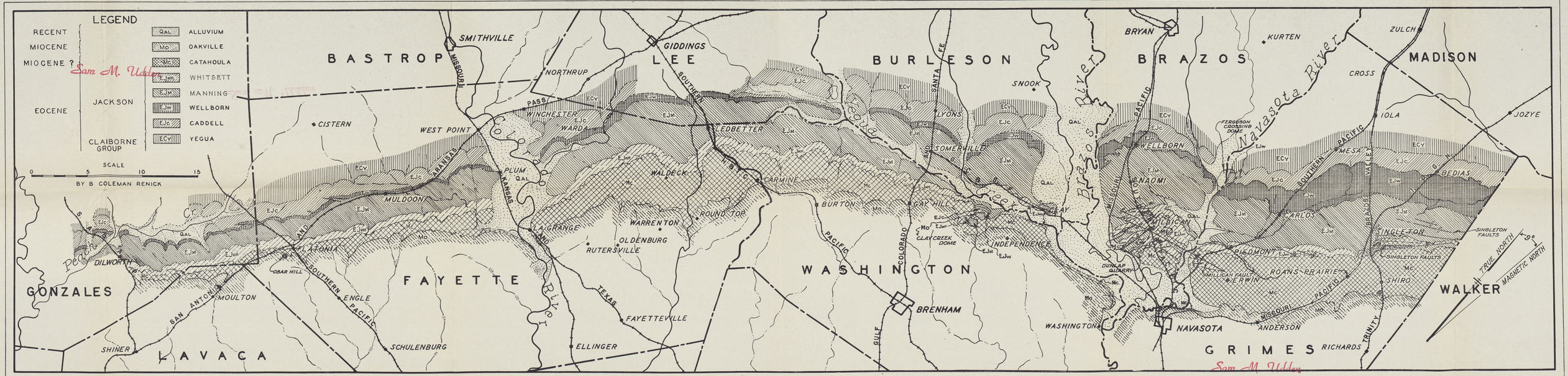
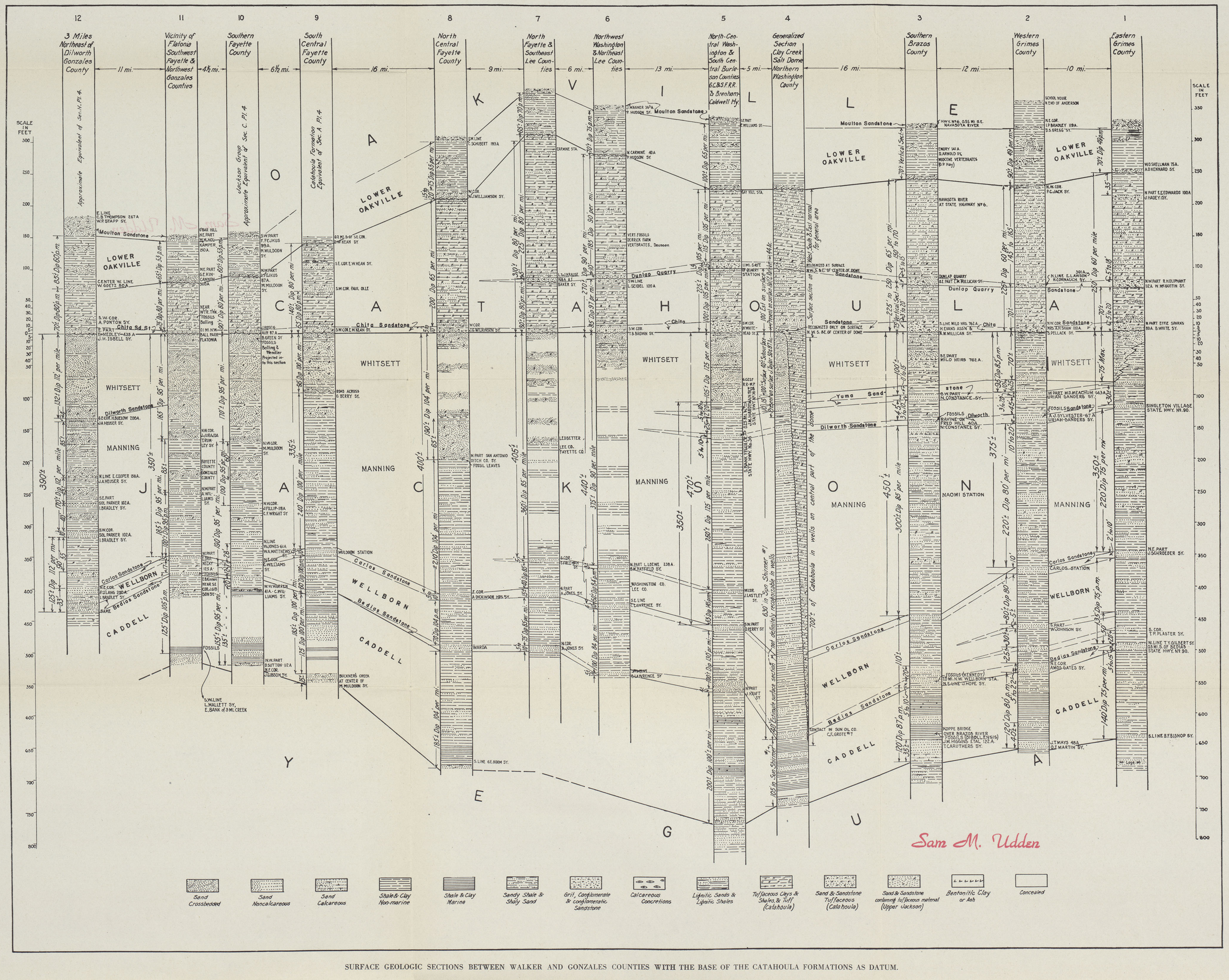


CHART SHOWING SYNONYMY OF GEOLOGIC NAMES.

Sam M. Udden



GEOLOGIC MAP OF AREA BETWEEN WALKER AND GONZALES COUNTIES.

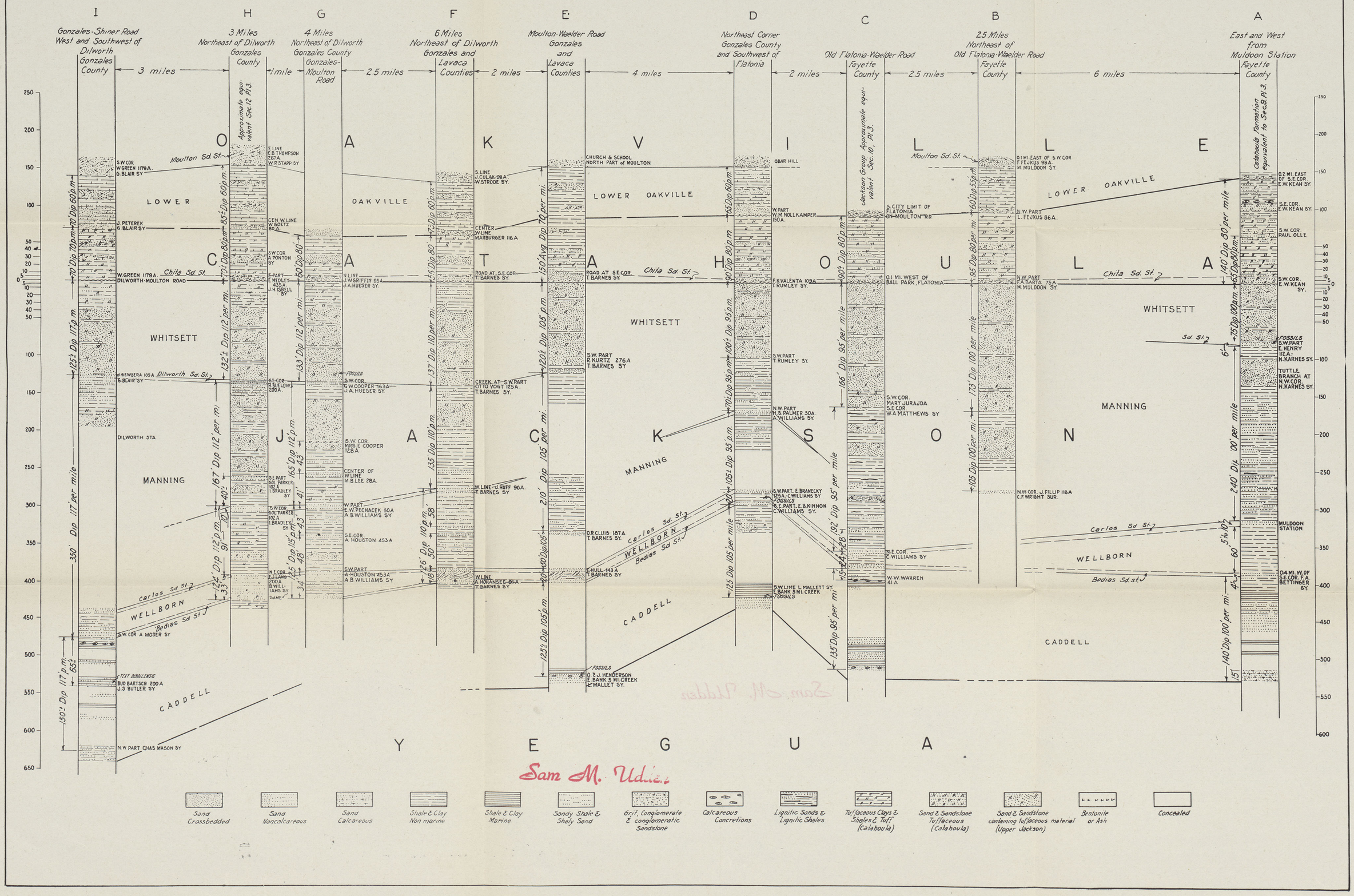


SURFACE GEOLOGIC SECTIONS BETWEEN WALKER AND GONZALES COUNTIES WITH THE BASE OF THE CATAHOULA FORMATIONS AS DATUM.

SURFACE GEOLOGIC SECTIONS BETWEEN WALKER AND GONZALES COUNTIES WITH THE BASE OF THE OAKVILLE FORMATION AS DATUM.

LEGEND

Sand Crossbedded
Sand Noncalcareous
Sand Calcareous
Shale & Clay Non-marine
Shale & Clay Marine
Sandy Shale & Shaly Sand
Grit, Conglomerate & conglomeratic Sandstone
Calcareous Concretions
Lignitic Sands & Lignitic Shales
Tuffaceous Clays & Shales & Tuff (Catahoula)
Sand & Sandstone Tuffaceous (Catahoula)
Sand & Sandstone containing tuffaceous material (Upper Jackson)
Bentonitic Clay or Ash
Concealed



SURFACE GEOLOGIC SECTIONS BETWEEN SOUTHERN FAYETTE AND NORTHERN GONZALES COUNTIES WITH THE BASE OF THE CATAHOULA FORMATION AS DATUM.

Sam M. Udden

GEOLOGIC MAP OF A PART OF BURLESON, BRAZOS, AND GRIMES COUNTIES, TEXAS

BY B. COLEMAN RENICK

Base map by Edgar Tobin Aerial Survey ~ San Antonio, Tex.

EXPLANATION

- GRANT OR SURVEY LINE
- COUNTY AND SURVEY LINE
- COUNTY LINE
- STATE LINE
- LINES VISIBLE ON AERIAL PHOTO
- STATE HIGHWAY
- SECONDARY ROADS
- TRAM ROADS
- PIPE LINES
- RAILROAD
- TRANSMISSION LINE
- LEVEE
- CANAL

GRAPHIC SCALE

3,000 0 3,000 6,000 9,000 12,000 15,000 18,000 FEET

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 VARAS

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 METERS

1 0 1 2 3 4 5 MILES

APPROXIMATE SCALE 1" = 5280 FEET.

LEGEND

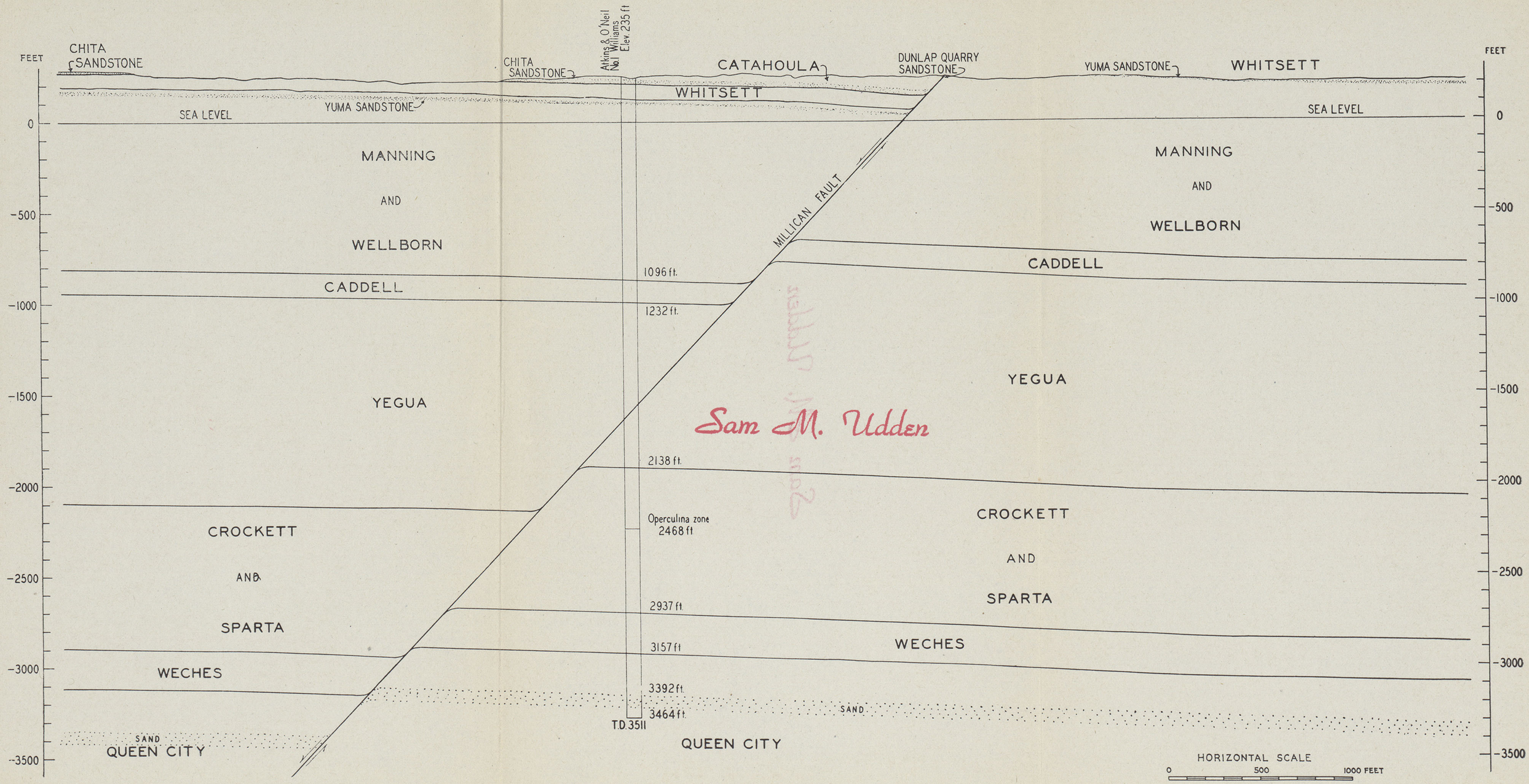
Sam M. Udden

RECENT	PLEISTOCENE		MIOCENE (OAKVILLE FORMATION)		MIOCENE?	EOCENE					
						WHITSETT FORMATION	MANNING FORMATION	WELLBORN FORMATION			CADDELL FORMATION	YEGUA FORMATION
Qal	Qlt	Qht	Mom	Mol	Mc, Mcd, Mcc	Ewha, Ewh	Emy, Emd, Em	Ewlc	Ewlm	Ewlb	Ec, Ecb	Ey
Alluvium	Low level terrace deposits	High level terrace deposits	Middle Oakville with Moulton sandstone at base.	Lower Oakville	Dunlap Quarry - Mcd, and Chita - Mcc, members in lower part.	Ewha Ash beds	Yuma-Emy and Dilworth - Emd sandstone members in upper part.	Carlos sandstone at top.	Middle Wellborn	Bedias sandstone at base	Unnamed sandstone at base - Ecb.	

CONTACT INFERRED · FAULT · FAULT INFERRED · DIP AND STRIKE · QUARRY · SPRING · FOSSIL LOCALITY · FOSSIL LEAVES · DRY WELL

Sam M. Udden

A. HOEN & CO., LITH.



GEOLOGIC CROSS SECTION SHOWING THE STRUCTURE OF THE MILLICAN FAULT IN SOUTHERN BRAZOS COUNTY ALONG NEW (CONCRETE) STATE HIGHWAY NO. 6.